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This study deals with the process of reaching social decisions that involve low-probability, high consequence outcomes. It is in 3 major parts. Part I reviews the two main classes of criteria proposed for social decisions: (1) market mechanisms and cost-benefit analysis and (2) the approaches of Rawls and Buchanan to arrive at a social consensus. The authors propose an eight element criteria for evaluating a social decision process capable of application in judicial, legislative, academic, and managerial situations.

Parts II and III are case studies of different decision procedures. The former inspects the administrative law procedure using the U.S. EPA chlordane/heptachlor suspension hearings for example. The legal procedure is concluded to be a forward-looking decision process in an effort to increase social acceptability of the outcome. The latter examines the disjointed decision procedure concerning the disposal of nuclear waste. In both cases the eight criteria proposed in Part I nevertheless provide a useful tool for evaluating the process.

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FOREWORD

Effective regulatory and enforcement actions by the Environmental Protection Agency would be virtually impossible without sound scientific data on pollutants and their impact on environmental stability and human health. Responsibility for building this data base has been assigned to EPA's Office of Research and Development and its 15 major field installations, one of which is the Corvallis Environmental Research Laboratory (CERL).

The primary mission of the Corvallis Laboratory is research on the effects of environmental pollutants on terrestrial, freshwater, and marine ecosystems; the behavior, effects and control of pollutants in lake systems; and the development of predictive models on the movement of pollutants in the biosphere.

This study was initiated by the Washington Environmental Research Center, Office of Research and Development, Washington, D.C. and completed at the CERL, Office of Research and Development, Corvallis, Oregon.

A. F. Bartsch
Director, CERL

PREFACE

Industrialized societies have long viewed technological innovation as a primary means of obtaining ever higher levels of social well-being from limited resources. Increasingly, though, new technologies bring with them possible environmental consequences which are highly adverse, albeit with a very low probability of occurrence: such technologies thus involve environmental risk, a social problem that differs in nature from the familiar air or water pollution problem, and is of growing importance.

Two technologies involving environmental risk have been selected for intensive case studies in this report. They are: (1) widespread use of pesticides which may have toxic, carcinogenic, mutagenic, or teratogenic effects; and (2) disposal of nuclear wastes. Other examples of environmental risk problems include: design and siting of nuclear reactors; use of nuclear explosive devices for stimulating the extraction of underground natural gas; ozone depletion resulting from fluorocarbon emissions; exploitation of subsurface oil, especially near scenic coastlines, such as Santa Barbara; adoption of drugs having a small probability of extreme biological damage, such as thalidomide; dangers that experiments with recombinant DNA will create a new disease against which mankind has no natural defense; and the shipment and handling of highly flammable liquified natural gas.

A number of characteristics distinguish problems of environmental risk from environmental pollution problems: (1) The probability of occurrence is so low and the underlying mechanism often so uncertain that even the most informed estimates of risk are highly subjective and vary widely. (2) The level of potential damages is frequently catastrophic and overwhelms the underwriting capability of the private insurance mechanism, or at times even the possibility of reasonable public provision. (3) Many environmental risks are latent; they may be borne unknowingly and involuntarily for long periods of time. (4) The consequences of some environmental risks, once incurred, cannot be reversed for long periods of time--in the case of nuclear wastes the risk may extend for tens of thousands of years. (5) Environmental risk situations typically involve collective exposure of large segments of society. (6) Parties who bear environmental risk typically receive a disproportionately small share of the benefits from the undertaking. Finally, (7) for many risks it is difficult to establish a legally defensible cause-and-effect relationship between the parties liable for the event and those who bear the losses.

The preceding characteristics make environmental risk problems hard to manage through existing regulatory, legal and economic institutions. Technologies that involve environmental risk thus face society with extremely difficult collective decisions. Both the liability issue and the magnitude of potential adverse consequences raise a number of important social questions such as: Does the activity infringe civil liberties or other constitutional guarantees? To what extent is the public willing to trust the risk assessments of those who are promoting the activity and are most likely to benefit from it? What should decision makers do when recognized authorities give widely varying estimates of risk and are in almost total disagreement concerning recommended action? How can we arrive at a socially acceptable decision? Are there "optimal" decisions? Will decisions that are optimal by an "objective" cost-benefit criterion also be socially acceptable? What is the risk of adopting decisions or policies that are not socially acceptable? Is sabotage, revolution and possible destruction of democratic society at risk? If social acceptability is an important criterion, how does one improve the decision process so as to make decisions more acceptable? It is questions such as these which have motivated this study, and which it addresses to the extent possible.

Events of the nineteen seventies have illustrated again and again the need for a better understanding of these issues. Example: controversy concerning the construction of nuclear plants has not diminished, despite increased experience with nuclear power. Even in regions where energy is in short supply and the cost is high, such as New Hampshire, thousands of people regularly turn out to protest a nuclear plant whose construction is well-advanced. Another example: a large number of scientists have proposed establishment of a new institution, to be called a "science court," because they do not have sufficient confidence in the existing decision processes. Another example: in Japan thousands of demonstrators get involved in sabotage, mass demonstrations and mass arrests to prevent opening of the new Tokyo airport, because the decision process is not socially acceptable.

Economists, decision theorists and political scientists have made considerable progress in applying analytical techniques to the process of social choice. However, these techniques rarely focus on situations involving low probability, high consequence outcomes. Decisions involving risk and uncertainty have been studied, but principally in the context of international policy and military situations. More work is needed on how to arrive at socially acceptable choices when a technology involves low probability but very high consequence outcomes.

The study team was aided greatly throughout the project by an Advisory Panel composed of Kenneth Arrow, Otto Davis and Roland McKean. To these three individuals we wish to express our sincere appreciation for their helpful advice and comments. The authors also wish to thank the many individuals from the Environmental Protection Agency who cooperated with us during the study.

The study team for this project consisted of: Mark Kendall and Ivars Gutmanis from the National Planning Association; and John Haldi and Thomas Vietorisz from Haldi Associates, Inc. Primary responsibility for individual components of this study was as follows. Principal investigator for Part I, Theoretical Aspects: Mark Kendall (with the exception of the subsection in Chapter 3 entitled "The Pareto Criterion," which was written by Kenneth Arrow). Principal investigator for Part II, Case Study of Pesticides: John

Haldi. Principal investigator for Part III, Case Study of Nuclear Wastes: Ivars Gutmanis.

To all those who offered assistance, advice, and helpful criticism, the authors wish to express their thanks. Any errors or shortcomings of the study are, of course, their responsibility alone.

* * *

The data, analyses and conclusions in this report are solely the responsibility of the authors and are not to be interpreted as expressing those of the National Planning Association or of the members of its Board of Trustees, committees and staff.

ABSTRACT

This study deals with the process of reaching social decisions that involve low-probability, high-consequence outcomes. It is divided into three major parts:

I. Theoretical considerations
II. Case study of chlordane and heptachlor pesticide regulation
III. Case study of nuclear waste disposal

Part I reviews the two main classes of criteria which have been proposed for such social decisions: (1) approaches based on the market mechanism and its extension, cost-benefit analysis, which is the operational method of implementing market-based criteria where full market information is lacking; and (2) approaches associated with Rawls and Buchanan, which focus not only on outcomes, but also impose a set of minimal constraints on the process whereby decisions and social consensus are reached. While formal optimality (in a Pareto or cost-benefit sense) is important, social acceptability of the process used to arrive at decisions is seen to be equally important. Part I concludes by proposing a set of eight criteria for evaluating a social decision process. These criteria are capable of being applied to a wide range of decision processes, be they deliberations before Congress, the Courts, an administrative law judge, the National Academy of Sciences, or an internal executive process. Applicability of the criteria is then explored in the context of two case studies.

The pesticide case study focuses on the chlordane/heptachlor suspension hearings of the U.S. Environmental Protection Administration as an example of the functioning of one particular decision process, the administrative law procedure. Applicable law mandates that the Administrator base his decision concerning use of a given pesticide on a cost-risk-benefit criterion. Since such analysis is not, per se, fully understood or accepted by many segments of society, the law also prescribes that the analysis be subjected to an adversary procedure conducted before an administrative law judge. The legal process is thus used as a forward-looking decision process in an effort to increase social acceptability of the outcome.

The case study on nuclear wastes examines a distinctly different decision situation. While EPA has sole responsibility for pesticide decisions, no agency has sole responsibility for the disposal of nuclear wastes. Certain key decisions in this area still remain with Congress. The Nuclear Regulatory Agency and Department of Energy have inherited major roles in the regulation of nuclear power, but many other agencies are also involved one way or another in decisions concerning or affecting nuclear wastes. This decision process is poorly articulated. The eight criteria proposed in Part I nevertheless provide a useful tool for evaluating the process.

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Part I

THEORETICAL CONSIDERATIONS

1. Introduction

A category of environmental problems of increasing importance involves situations characterized by high consequence outcomes which have a low probability of occurring. Examples of situations involving such environmental risk include; (1) the risk of ozone depletion due to emissions of fluorocarbons; (2) the risk of radioactive leakage from nuclear accidents or from disposal of nuclear wastes; (3) the risk of creating a new disease, for which there is no known cure or vaccination, from experiments with recombinant DNA; or (4) the risk that residues for various pesticides or other chemicals may be carcinogenic, mutagenic or teratogenic.

Environmental risk problems involve a number of considerations that differ substantially from what might be described as classical or traditional environmental problems of air and water pollution. For example, uncertainty regarding events and outcomes is somewhat less in classical pollution problems. That is, if certain chemical wastes are dumped into rivers, the downstream effects on fish or oxygen content can now be predicted (and measured) with a fair degree of certainty. The uncertainty attending situations described above as environmental risk is greater by at least an order of magnitude. This uncertainty, coupled with several other important distinguishing characteristics, makes problems of environmental risk far less susceptible to management through existing social decision processes. Debate and disillusionment concerning our decision process already exist. It is important, therefore, that we develop explicit criteria for evaluating the decision process itself.

In the context of this study, the social decision process is defined broadly. It includes the legislative process in Congress and the various regulatory processes established by Congress, (e.g., EPA, FDA, etc.), including judicial review of administrative decisions. Also included, to some extent, are the deliberations and procedures of the National Academy of Science. While not an official part of the decision process, the National Academy is a well-established institution whose opinions weigh so heavily with elected officials that it is accorded at least semi-official status. Moreover, some of the Academy's procedures have been criticized by a number of scientists, some of whom have recommended that the Academy's deliberations be replaced, at least in part, by a new institution referred to in the literature as a Science Court.

By way of overview, Part I of this report addresses some fundamental considerations that confront the decision process. The purpose is to develop a set of criteria for evaluating alternative decision processes. In Part II, a case study of chlordane and heptachlor includes a detailed description of the social process for regulating pesticides. The principal concern with low probability, high consequence events is that use of some pesticides may cause unintended, widespread effects, such as cancer or animal kills. Pesticide regulation is primarily the responsibility of the Environmental Protection Agency. Nuclear waste disposal, in Part III, is the other case study. Obviously, waste disposal is an integral part of the nuclear fuel cycle. Use of nuclear power and accompanying problems of waste disposal have been subject to wide public debate. The agency primarily charged with making social decisions concerning the appropriate method of waste disposal is the Nuclear Regulatory Commission (a successor to the Atomic Energy Commission). In contrast to pesticides, however, the current decision process for nuclear wastes is far more diffuse.

The next chapter summarizes the important characteristics of social decisions involving low probability, high consequence outcomes as exhibited in the two case studies. Chapter 3 discusses various approaches to evaluating social decisions with the unique characteristics described in Chapter 2. Our criteria for evaluating social decision-making processes involving low probability, high consequence occurrences are developed in Chapter 4. These criteria are subsequently applied in Chapter 10 to the pesticide regulatory process; in Chapter 16 they are applied to nuclear waste disposal decisions.

2. Distinguishing Features of High Consequence, Low Probability Occurrences

Social decision-making involving low probability, high consequence occurrences has a number of interesting and difficult aspects. These are discussed in detail in the two case studies which accompany and are an integral part of this report. Succinctly, special features of environmental risk problems developed in the case studies are:

1. Aggregation of preferences
2. Limited knowledge
3. Uncertainty and irreversibility
4. Intergenerational effects
5. Distribution of benefits vs. risks
6. Counter risks

Each of these features raises theoretical issues that need to be resolved by an acceptable social decision process.

Aggregation of Preferences

Most individuals are risk adverse. This implies that the satisfaction a person receives from a certain income of $10 exceeds the satisfaction of a 50 percent chance of a zero income and a 50 percent chance of a $20 income. 1/ Thus, it is necessary to know preference functions (i.e., risk valuations) as well as possible outcomes when evaluating social decisions which entail low probability but high consequence outcomes.

Limited Knowledge

Decisions concerning pesticides and nuclear waste disposal test the limits of our knowledge. We know for instance that chlordane and heptachlor persist in the food chain. Evidence also indicates that they are carcinogenic in rats, but we do not know the dose-response pattern with any significant degree of certainty. The suspension hearing for chlordane and heptachlor established that there is reason to believe that continued use of these two pesticides may result in a higher incidence of cancer among humans. However, it was not possible to establish the relationship between specific use levels of chlordane and heptachlor and specific increases in the incidence of either cancer in general, or among specific groups who may be more susceptible to the disease. Also, it was not possible to specify with certainty the increase in use of substitutes for chlordane and heptachlor and the substitutes' carcinogenic effects. This uncertainty -- lack of knowledge -- is particularly important because chlordane and heptachlor are effective pesticides. Lack of knowledge makes difficult the application of an efficiency criterion (or any other standard).

Knowledge gaps for nuclear waste disposal are probably larger than for pesticides. There does not exist an accepted technology and set of social institutions that can assure a well-defined distribution of risks associated with disposing of nuclear wastes. Some are willing to assume, given man's historical inventiveness, that suitable technologies and institutions will be developed; they urge continued development of nuclear power. Others are unwilling to make this assumption. They argue that risks associated with all present proposals for waste disposal are either too high or are unknown. This is not dissimilar to the situation encountered with pesticides. Benefits of increased nuclear power, like the benefits of chlordane and heptachlor for increased food production, can be reasonably well-specified, but the link between increased use of nuclear power and nuclear "pollution", like the link between continued use of chlordane and heptachlor and cancer, is not well-specified. Even in a world where the social decision maker knew every individual's risk preference, the limits of knowledge would prevent a suitable aggregation of these risk preferences, since we do not know the distribution of risk.

Finally, infrequent observation of a bad occurrence, implied by low probability, makes it difficult to determine the correct response to a bad occurrence. A large number of experiences with a bad occurrence generally provide sufficient information to learn the "best" response. For low probability events, circumstances of a bad occurrence are unknown, and hence, possible responses are unknown. Finally, a low probability, high consequence occurrence makes any type of learning (observation or experimentation) very expensive.

Uncertainty and Irreversibility

In most cases, uncertainty comes from two sources. First is lack of knowledge. For example, there are significant differences of opinion concerning the long-term implications of various forms of nuclear waste disposal. Second is the pure probabilistic nature of many problems requiring social decisions that involve low probability, high consequence occurrences. In a world of perfect knowledge, certain components of the nuclear waste disposal problem would remain probabilistic since nature is, in part, stochastic.

Assume for the moment that decisions are evaluated as to whether they approximate the competitive market outcome. With given expectations, at any point in time the competitive market tends to balance the otherwise conflicting expectations of agents in the economy. One individual's expectations concerning future prices and states of the world might be significantly different from another's. Also, attitudes toward risk may differ significantly. For example, expectations of all agents in an economy are not the same nor are their risk preferences identical. However, the private economy has historically been able to find a set of prices and quantities that balance conflicting expectations and attitudes toward risk.

If an individual sees a set of prices and quantities that he did not expect, he revises his expectations, and a new equilibrium may be reached. Agents adjust their holdings of stocks, bonds, commodities and other goods in response to their revised expectations. They may "hedge their bets." They may suffer windfall monetary losses or gains, but seldom do they experience a windfall loss or gain that is not reversible at some cost. In the absence of externalities, the impact is on the agent making the decision, not on others.

One of the major differences between this private balancing of expectations and a social decision concerning nuclear waste disposal or the use of chlordane and heptachlor, is that many of the possible outcomes are not reversible. If storage of nuclear waste in salt mines does, through some unknown means, pollute the Western watershed, we can revise our expectations concerning the feasibility of nuclear power but we cannot reverse the impact of our incorrect expectations. 2/ Likewise, the discovery that the use of X pounds of chlordane per year increases the incidence of cancer by Y percent will lead to a revision in our expectations. However, given the pervasiveness of pesticide residues in the food chain, the impact of our initial decision may be irreversible for many people. Thus, the consequence of a bad occurrence may not be technically reversible, or may only be reversible over such a long period that, given some positive rate of time preference, it may as well not be reversible.

The private market economy, with the help of bankruptcy law protection, permits individual economic agents to revise expectations and, in at least some sense, reverse their losses, for a price within a reasonable time period, if they are wrong. This reversibility permits the efficiency criterion to maintain its validity as a suitable framework for analyzing competitive markets. The irreversibility of certain decisions concerning low probability, high consequence occurrences coupled with sensitivity to expectation changes (see Chapter 3) raise significant questions concerning validity of the efficiency criterion for evaluating these social decisions.

Intergenerational Effects

The requirement to consider intergenerational effects is important given the effect of uncertainty and 80,000 year half-lives. The benefits of nuclear energy are significant. It may be relatively cheap, it relieves our dependence on foreign sources, and it would be an almost inexhaustible source of energy with development of the breeder reactor. However, waste disposal, given present and reasonably foreseeable technologies, requires "a diligence and longevity of our social institutions that we are quite unaccustomed to." 3/

Consideration of intergenerational effects implies that the most sensitive variable for any social decision, using traditional benefit-cost analysis, is the interest rate. The literature is replete with discussions about the "optimal" social interest rate. These arguments usually search for an interest rate that will assure that decisions concerning investments in public capital will satisfy the Pareto criterion by being consistent with the private and public markets. Taxes and other considerations generally imply that an appropriate social interest rate is lower than the corporate return on investment. 4/ An obvious question is whether these benefit-cost-risk assessments are accurate. Even if they are, the uncertainty of nuclear waste disposal procedures and the associated intergenerational comparisons, may imply that these assessments, with their implied acceptance of an efficiency criterion, are not sufficient. For example, Kneese states:

> It is my belief that benefit-cost analysis cannot answer the most important policy questions associated with the desirability of developing a large-scale fission-based economy. To expect it to do so is to ask it to bear a burden it cannot sustain. . . These questions are of deep ethical character. 5/

The ethical character of the nuclear debate is whether (or, under what conditions) the present generation has the right to impose on future generations the uncertainties associated with a fission-based economy. If we do not know all the risks involved and if we do not know the preferences of future generations, do we have the right to impose these uncertainties? The responsibility for caring for the wastes generated by a fission-based economy will fall to future generations. Does the present generation have the right to impose this responsibility? If it does, under what conditions?

If one accepts the concept of maximizing expected utility over time, with time partitioned into today and tomorrow, then the real interest rate observed today is composed of:

(a) pure time preference;
(b) a risk premium; and
(c) after removing time preference and the risk premium, a factor that reflects the real rate of economic growth.

In order to develop a suitable social interest rate, it is necessary to examine each of these components. It has long been argued, on grounds of rationality as well as ethics, that there should be no pure time preference in the absence of uncertainty concerning death. Sidgwick maintains that, in the absence of uncertainty, rationality implies an impartial concern for all parts of our life. Mere differences in time would be irrelevant when evaluating the utility of goods at various points in time. If the universal good and individual good are similar in essential respects, social time preference should be zero. 6/

Since the risk premium is most difficult for our purposes, we will consider the third element next. If future generations are expected to be "better off" due to technological change and capital accumulation, then it is rational and ethical to discount future values at a rate that equates the utility offered by the total output of the economy at each point in time. If the goods produced next year will give two percent more total utility than the goods produced this year, then fairness requires that sacrifices in utility today be balanced against future utility increases. Thus, economic growth implies that the third component should be positive.

The second component in the observed market interest rate, the risk premium, is particularly difficult to handle in social decisions for low probability, high consequence occurrences. For some social investment decisions, the risk premium can be ignored since the benefits and costs of any one social investment are small relative to the wealth of any one individual, which offsets any substantial risk aversion held by members of society. 7/ However, risks arising from nuclear waste disposal or pesticide residues can possibly be large to all members of society, present and future. We do not know the shape of present or future utility functions, and hence attitudes toward risk, although it is necessary to estimate an appropriate risk premium in order to employ the usual benefit-cost-risk analysis. This requirement is probably so substantial as to make it impossible to use, unhesitatingly, the usual benefit-cost-risk analysis in making social decisions for low probability, high consequence occurrences. The result of any long-term benefit-cost analysis is sensitive to the interest rate, and reasonable bounds on a risk premium may not exist, since the risks are not independent over time.

Distribution of Benefits vs. Risks (costs)

A benefit-cost analysis of a social investment usually attaches no explicit value to the distributional consequences of the investment. It is often argued, however, that these effects should be taken into account "on the side." For both pesticides and nuclear wastes, the re-distribution of costs and benefits may be substantial and asymmetric. Also, restricting pesticides or preventing waste disposal hazards might yield benefits that differ geographically as well as temporally. In the case of pesticides, the benefit of limiting a pesticide with persistent residues and probable carcinogenic effects is generally assumed to accrue to all of society. At first blush, this assumption may seem appropriate. However, if one admits differential values of human life and assumes that these differentials are positively related to future, expected income streams, then the value of regulating a pesticide will accrue to those with higher expected income streams. (Or, if people value risks differently, regulation of a pesticide will give greater benefits to those who are more risk adverse.)

The cost of regulating or discontinuing the use of a pesticide generally accrues to (1) landowners or owners of specialized farm resources, to the extent that they cannot shift their increased costs of food production to the consumer, and (2) to the consumer, to the extent that the increased costs of production can be passed along. If, for simplicity, all increased costs were shifted completely to the final consumer, all consumers would face roughly the same increases in food cost. However, in terms of welfare loss, those consumers with relatively lower incomes, and hence a relatively higher portion of their budgets devoted to food, would experience a larger welfare loss. 8/ Thus, in this admittedly simple model, the primary beneficiaries of limitations on the use of pesticides are the higher income groups.

A similar asymmetric distribution of costs and benefits can be attributed to limitations on nuclear waste disposal, since those who have higher expected income streams would tend to offer more for decreased threats to their income stream from unforeseen consequences of nuclear waste disposal. 9/ Also, a higher price of energy, because energy has a relatively low income elasticity, would adversely affect lower income groups.

Inequities of the intragenerational distribution of benefits and costs, for both pesticides and nuclear waste disposal, might be corrected by changes in the tax system. However, if the continued use of pesticides or the increased use of nuclear power does offer a significant threat to society as we presently know it, then future groups might suffer a higher cost for deregulation of pesticides and increased nuclear waste disposal, relative to the present generation. This could not be easily corrected by changes in the tax system. Thus, there is need for a more explicit consideration of the intragenerational and intergenerational distribution of benefits, costs and risks.

Counter Risks

For both case studies, one side of the benefit-cost relationship seems reasonably well-defined. In the case of pesticides, a primary risk consideration is persistence of the pesticide residues and an associated increase in the incidence of cancer. Benefits of decreased use of chlordane and heptachlor are uncertain, while it is generally agreed that the costs of decreased use of these pesticides are fairly well specified. It is generally accepted that, through the use of substitute chemicals, the costs of decreasing the use of chlordane and heptachlor are small relative to expected benefits (except for the possible carcinogenic effects of substitutes).

If regulation and limitations on the use of pesticides continue, it is reasonable to speculate on longer term uncertainties associated with the cost estimates. For example, pesticide regulation is sequential. That is, each pesticide is considered in turn, and the costs of its regulation are estimated assuming no further regulation of pesticides. If, over time, increased limitations on other pesticides effectively limit the ability to control particular pests, the costs of limiting the use of chlordane and heptachlor might be much larger, after other pesticides are limited in their use, than when the initial decision was made. More serious, substitutes for chlordane and heptachlor might have more detrimental effects than either of the two original substances. Thus, if chlordane and heptachlor are not available to substitute for the possibly more dangerous pesticides, the present regulatory mechanism may overestimate the costs of regulating the latter. In other words, each sequential decision might be valid, while the total set of decisions is not, since pesticides prohibited earlier in the sequence are not considered "available" substitutes.

The problem of risks "on the other side of the equation" is more substantial for nuclear power. Whereas costs and associated risks of waste disposal are subject to a high degree of uncertainty, many individuals, at least until recently, have been willing to concede the accuracy of order-of-magnitude estimates of the benefits from nuclear power. Since establishment of nuclear power requires a relatively long lead time and generates relatively long-lived plants, most benefits of nuclear power will accrue at some future date. Obviously, estimating benefits requires a fairly precise estimate of the future demand for energy. If this estimate cannot be made with a reasonable degree of precision, risk-assessment problems occur in estimating the benefits of nuclear power. This estimate also requires assumptions concerning both the future state of world (oil) diplomacy and the availability of substitute energy sources.

Summary

This chapter has focused attention on several important characteristics that distinguish problems of environmental risk from the more traditional pollution problems. Classical benefit-cost-risk analysis can guide social decisions for low probability, high consequence occurrences. However, the decision process must also consider (1) factors that, due to measurement problems, cannot be included in the quantitative benefit-cost-risk analysis; and (2) ethical elements such as preventing the tyranny of one group over another (or, one generation over another).

Notes to Chapter 2

1. Milton Friedman and L. J. Savage, "Utility Analysis of Choices Involving Risks," Journal of Political Economy. Vol. 56, (August 1948), pp. 279-304.

2. This also limits the use of a Baysian approach for estimating the probabilities since (1) bad occurrences happen infrequently, which gives few observations for estimating and revising probability estimates, and (2) irreversibility implies that a bad occurrence limits the use of a new Baysian probability estimate.

3. Alan M. Weinberg, "Social Institutions and Nuclear Energy," Science (July 7, 1972), p. 31.

4. For example, see Arnold Harberger, "Professor Arrow and the Discount Rate" in Project Evaluation. (Chicago: University of Chicago Press, 1976).

5. Alan B. Kneese, "The Faustian Bargain," Resources (September 1973), p. 1.

6. See John Rawls, A Theory of Justice, pp. 293-94 for this interpretation of Sidgwick.

7. See Kenneth J. Arrow and Robert C. Lind, "Uncertainty and the Evaluation of Public Investment Decisions," American Economic Review (June 1970), pp. 364-78.

8. If all income groups have the same price elasticity of demand for food.

9. If bad occurrences from nuclear waste disposal are limited geographically, the greater mobility of higher income groups would decrease the value they place on decreased generation of nuclear waste.

3. Alternative Approaches to Social Decision-Making

A fair spectrum of criteria for evaluating decisions of social institutions ranges from (1) Pareto optimality, constrained by an appropriate initial distribution of endowments, to (2) Rawls' maximin principle, constrained by equality of opportunity for all, to (3) Buchanan's claim that social institutions are just if they are entered into freely by individuals. These three sets of criteria do not describe the complete spectrum. 1/ They are sufficiently diverse, however, to provide a good basis for developing criteria that can be used to evaluate the social decision process. The following discussion summarizes these procedures.

The Pareto Criterion

Pareto optimality or efficiency requires that all agents of the economy be brought into trading arrangements and that trades take place until there are no more mutual gains from further trade between the agents. The Pareto criterion provides the rationale for a market-based decision process. For nonmarket decisions by government, the Pareto criterion is the rationale underlying the widespread use of benefit-cost analysis. The trading economy is said to be efficient (or optimal) if the final exchange of goods is a point on the familiar contract curve. This result holds with the usual assumptions of continuity, insatiability and transitivity of preference orderings.

Neoclassical analysis can be used to define Pareto efficient decisions under a variety of conditions. However, the unique characteristics of environmental risk problems are only beginning to be widely recognized, and Pareto efficient decisions have not been fully worked out for such situations. The following notes represent tentative steps towards a theory of evaluating publicly manageable risks to life. They are considered to be correct insofar as they go, although they clearly leave out a large number of problems that arise in practice.

The static case: objective function and instruments. The individual is supposed to have a risk of dying. If he survives, he consumes and derives satisfaction from his consumption. According to the usual expected-utility theory, his choices are governed by the desire to maximize,

$$(1-p_i)\ U_i\ (\text{consumption}) + P_i\ U(\text{death}), \qquad (1)$$

where,

P_i = probability of death, U_i = utility of individual i.

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As a first approximation, it seems reasonable to consider the utility of death to be a constant, which, without loss of generality, we may take to be zero. There are two possible reservations to this assumption: (1) the manner of death may matter to the individual, so that he may be willing to devote his own resources to changing the conditions under which death occurs or to protecting against one form of health hazard even if it only makes inevitable another form; (2) care for the family or others means that, in event of death, utility depends upon the bequest or insurance protection. Both points can be met by extension of the present arguments; but, in any case, these are both probably second-order considerations. Setting the utility of death equal to zero means that utility functions are not only cardinal, as in the usual expected-utility theory, but have also a fixed origin, hence unique up to positive multiplication (what the psychologists call ratio scales). Then the maximand is,

$$(1 - p_i)U_i(c_i), \qquad (2)$$

where

$$c_i = \text{consumption of individual i.} \qquad (3)$$

The novel aspect of resource allocation in the theory of optimal safety is that the probability, p_i, of death is itself controllable by allocating resources to it. The general assumption to be made here is that the probability can be affected by both public and private measures. This is clearly realistic: the probability, p_i, is the resultant of a great many separate processes, some essentially private in nature, some public (in Samuelson's sense). Let,

x = public expenditures on decreasing probability of death,

s_i = private expenditure of individual i on decreasing probability of death, (4)

and we assume,

$$p_i = p_i(x, s_i). \qquad (5)$$

Our aim is to define a Pareto optimum of the maximands (2) with the assumption (5). We shall assume that resources are freely transferable between the public and private sectors and that, in any case, each individual will choose optimally in allocating his income between c_i and s_i.

To illustrate the analysis in the simplest case, assume first that there are no private effects on the probability of death, i.e., p_i is a function of x alone and not of s_i. Our resource constraint then is,

$$\Sigma c_i + x \text{ given.} \qquad (6)$$

In the usual way, we take arbitrary positive weights, w_i, for the maximands (2) and optimize for each such choice. The Pareto frontier is found by considering the allocations for all possible w_i's; equivalently, we eliminate the w_i's from the optimum conditions.

Maximize,

$$\Sigma w_i \, [1 - p_i(x)] \, U_i(c_i),$$

subject to (6). Let μ be the Lagrange parameter corresponding to (6). Then differentiation of the Lagrangian with respect to x yields,

$$-\Sigma w_i (dp_i/dx) \, U_i(c_i) = \mu, \tag{7}$$

while differentiation with respect to c_i yields,

$$w_i[1 - p_i]U_i'(c_i) = \mu$$

Multiply the i^{th} term on the left-hand side of (7) by,

$$1 = \mu/w_i(1 - p_i) \, U_i',$$

which clearly leaves it unchanged in value; then divide the resulting expression derived from (7) by

$$- \sum_i \left(\frac{1}{1 - p_i} \frac{dp_i}{dx}\right) \Big/ \frac{U_i'}{U_i} = 1 \tag{9}$$

To interpret (9), it is useful to interpret the factor U_i'/U_i. Start with a consumption level c_i and probability of death, p_i. If consumption is increased by an amount h, the individual will remain on the same indifference curve with a slightly higher probability of death; let that probability be $p_i(h)$, where, $p_i(0) = p_i$. Then

$$[1 - p_i(h)] \, U_i(c_i + h) = (1 - p_i) \, U_i(c_i).$$

Differentiate with respect to h:

$$- p_i'(h) \, U_i(c_i + h) + [1 - p_i(h)] \, U_i'(c_i + h) = 0$$

Set h = 0.

$$(1 - p_i) \, U_i'(c_i) \,/\, U_i(c_i) = p_i'(0). \tag{10}$$

Note that $p_i'(0)$ is the marginal increase in probability of death per unit increase in consumption. Its reciprocal would be the marginal compensation needed to offset a unit increase in probability of death, or, alternatively, the marginal expenditure the individual would be willing to make to reduce the probability of death (per unit reduction). Let, then,

$$c_i(p_i) = \text{consumption needed to compensate for change in } p_i, \qquad (11)$$

where the movements are along some specified indifference curve; then,

$$p_i'(0) = 1/c_i'(p_i),$$

and (10) can be written,

$$(1 - p_i)\, U_i'(c_i)/U_i(c_i) = 1/c_i'(p_i).$$

Substitution into (9) yields the perhaps unsurprising result,

$$-\sum_i c_i'(p_i)\ (dp/dx) = 1; \qquad (12)$$

the public expenditure, x, should be carried up to the point where the changes in individual probabilities of death, weighted by the individuals' monetary values of the change, sum to 1.

So far, there has been no way of determining the valuations c_i' objectively. Let us now suppose, as is reasonable, that in fact the probability of death may be affected by private as well as public decisions. In addition to consumption for each individual, there are also his expenditures on safety. Let,

$$s_i = \text{safety expenditures of individual } i, \qquad (13)$$

and we assume now,

$$p_i = p_i(s_i, x).$$

To find a Pareto optimum, we maximize,

$$\sum w_i\, [1 - p_i(s_i, x)]\, U_i(c_i),$$

subject to,

$$\sum (c_i + s_i) + x \text{ given.} \qquad (14)$$

Let μ again be the Lagrange parameter. Differentiation with respect to x, c_i, s_i, respectively yields,

$$-\Sigma w_i (\partial p_i/\partial x)\ U_i(c_i) = \tag{15}$$

$$w_i\ [1 - p_i]\ U_i'(c_i) = \mu, \tag{16}$$

$$-w_i\ (\partial p_i/\partial s_i)\ U_i(c_i) = \mu. \tag{17}$$

Note that equations (15) and (16) are identical with (7) and (8) except that the total derivative, dp_i/dx, has been replaced by a partial derivative, $\partial p_i/\partial x$. Hence, the subsequent manipulations leading to (12) remain valid:

$$-\Sigma c_i'(p_i)\ (\partial p_i/\partial x) = 1. \tag{18}$$

On the other hand, from (16) and (17), we have, by eliminating and dividing through by w_i,

$$\partial p_i/\partial s_i = (1 - p_i)\ U_i'(c_i)/U_i(c_i). \tag{19}$$

The derivative, $\partial p_i/\partial s_i$, represents the effect of private expenditures on the probability of death. In the original definition, $p_i = p_i(s_i, x)$, it may be useful to solve for s_i in terms of p_i and x; this function represents the amount of private expenditures needed to achieve a given probability of death, for given public expenditures. Then, $\partial s_i/\partial p_i$ is the marginal cost to the individual of a unit change in the probability of his death. By the usual inverse function theorems,

$$\partial s_i/\partial p_i = 1/(\partial p_i/\partial s_i).$$

Substitute into (19) and also use the equation preceding (12).

$$c_i'(p_i) = \partial s_i/\partial p_i; \tag{20}$$

at an optimum, the marginal willingness to pay for a unit reduction in probability of death should equal the marginal cost of such an improvement in terms of individual expenditures.

Notice also that an individual will, in allocating his own budget optimally, realize (20). Hence (20) provides a means of estimating from objective data the marginal values of decreases in probability.

The static case: several kinds of public safety expenditures. Suppose the probability of death for any individual can be affected in several ways by public expenditures, thus, by increased plant safety standards paid for by the government, by increased highway expenditure, or by increased police force. We assume,

$$p_i = p_i(s_i, x_1, x_2) \tag{21}$$

Then essentially the same results follow, with (15) being valid separately for x_1 and x_2, and therefore (18) replaced by the two conditions,

$$-\sum_i c_i'(p_i) \quad (\partial p_i/\partial x_j) = 1 \qquad (j = 1,2). \tag{22}$$

Subtracting the equation for j = 1 from that for j = 2 yields,

$$-\sum_i c_i'(p_i)\ [(\partial p_i/\partial x_2) - (\partial p_i/\partial x_1)] = 0 \tag{23}$$

The savings in probabilities of death attributed to each kind of expenditure, weighted by individuals' willingness to pay for safety should be equal. This provides a basis for judging the level of a new kind of public safety expenditure by reference to old ones.

There is a widespread argument for neglecting distributional effects in benefit-cost analysis on the grounds that the effects of the particular project under consideration are distributed in the population independently of the marginal social value of a dollar. Analogously, one could assume that the willingness to pay for safety is distributed among individuals independently of the differential effect of one public expenditure as against another. By elementary rules of statistics, independence implies that the left-hand side of (23) can be written,

$$-\ (1/N)\ [\sum_i c_i'(p_i)] \sum_i [(\partial p_i/\partial x_2) - (\partial p_i/\partial x_1)],$$

and since certainly,

$$\sum_i c_i'(p_i) > 0,$$

it follows from (23) that, if willingness to pay for safety is distributed in the population independently of the safety effect of shifting expenditures from one type to another, then optimality requires that,

$$\sum_i (\partial p_i/\partial x_1) = \sum_i (\partial p_i/\partial x_2),$$

i.e., so as to maximize the expected number of lives saved.

For its interest, we present the special case where each safety expenditure corresponds to an independent risk of death. That is, the probability of survival is the product of the probabilities of survival from different causes, each affected by a different category of expenditure.

$$1 - p_i = [1 - p_i^o(s_i)]\,[1 - p_i^1(x_1)]\,[1 - p_i^2(x_2)]. \tag{24}$$

Then, by differentiation with respect to the variables s_i, x_1, x_2, and multiplication by -1, we see,

$$\frac{\partial p_i}{\partial s_i} = \frac{1 - p_i}{1 - p_i^o}\,\frac{dp_i^o}{ds_i}, \tag{25}$$

$$\frac{\partial p_i}{\partial x_j} = \frac{1 - p_i}{1 - p_i^j}\,\frac{dp_i^j}{dx_j} \quad (j = 1,2). \tag{26}$$

The optimality criteria (22) for the margins of different kinds of government expenditures become,

$$-\sum_i (p_i)\,\frac{1 - p_i}{1 - p_i^j}\,\frac{dp_i^j}{dx_j} = 1 \quad (j = 1,2). \tag{27}$$

Note that $[(1 - p_i)/(1 - p_i^j)]$ is the probability of survival if the individual does not die from cause j.

We can substitute (25) into the criterion (20), which measures the willingness to pay for safety by the marginal contribution of private safety expenditures. Let,

$s_i^o(p_i^o)$ = private expenditure needed to reduce probability of death from private causes to p_i^o, (28)

so that $ds_i^o/dp_i^o = 1/(dp_i^o/ds_i)$. Then,

$$\frac{1 - p_i}{1 - p_i^o}\,c_i'(p_i) = \frac{ds_i^o}{dp_i^o}\ ; \tag{29}$$

the right-hand side may be more meaningful to calculate since it concentrates on the "technological" relation between probability of death affected by private expenditures and those expenditures.

Life-cycle analysis. This section analyzes the situation when people are considered as living an extended period of time. For simplicity, assume a number of people all live from 0 to T. For the ith individual, let

c_{it} = consumption at time t, (30)

s_{it} = safety expenditures at time t, (31)

$U_{it}(c_{it})$ = utility of consumption at time t, discounted back to time zero, (32)

$P_i(t)$ = probability of survival to time t. (33)

Then the individual's lifetime utility is given (assuming intertemporally additive utilities) by,

$$\int_o^T P_i(t)\, U_{it}(c_{it})\, dt,$$

and therefore a Pareto analysis seeks to maximize

$$\sum_i w_i \int_o^T P_i(t)\, U_{it}(c_{it})\, dt. \tag{34}$$

There are two kinds of constraints: those on production or the availability of resources in general and those on the relation between probability of survival and resources devoted to safety.

With regard to the first, we make the following simple assumption. Each individual is capable of producing something at any given age; product at any time can be converted to product at a later time at a growth rate r. There may be an initial accumulation of assets at time 0. We can therefore as usual discount all resources and expenditures back to time 0 at a rate r; but it must be kept in mind that both human resources and personal expenditures must also be discounted by the probability of survival. To simplify notation, define consumption to be the amount above and beyond the human resources from the same individual at any time t; since the utility function has a time subscript, this adjustment can be absorbed into the form of the utility function. Of course, c_{it} may, and usually will, be negative from some values of t, with this definition. Also define,

x_{ct} = public safety expenditures. (35)

Then total expected expenditures (net of human resources) at time t are,

$$x_t + \sum_i P_i(t)\ (c_{it} + s_{it}),$$

and therefore the resource constraint is,

$$\int_o^T e^{-rt}\ [x_t + \sum_i P_i\ (c_{it} + s_{it})]\ dt = \text{constant}, \tag{36}$$

the constant being the initial accumulation of assets.

We can construct a simple model of the interrelation between safety expenditures and the probability of survival as follows. The risks at different moments of time are assumed independent; the probability of death in any small period of time is a function of public and private safety expenditures during that period. More explicitly, by the usual laws of probability theory,

$$P_i(t + h) = P_i(t) \text{ Prob (survival to } t + h| \text{ survival to } t)$$

$$= P_i(t) \text{ [1 - Prob (death between } t \text{ and } t + h| \text{ survival to } t)].$$

This last probability is assumed to depend only on safety expenditures between t and t + h (for given t, i.e., the effect of age on probability of death is not excluded). Let $\overline{P}_i$ $(t + h\lambda t)$ be the probability of death between t and t + h, given survival to t. Then taking logarithms of both sides, subtracting x log $P_i(t)$ from both sides, dividing through by h, and letting h approach zero yields,

$$\dot{P}_i/P_i = -\lim_{h \quad 0} [\dot{\overline{P}} \ (t + h|t]/h = - p_{it} \ (s_{it}, x_t), \text{ say.} \tag{37}$$

From the assumption, p_{it} does depend only on safety expenditures in the interval (t, t + h) or h vanishingly small, hence only on expenditures at time t.

The maximization of (34) is subject to the constraints (36) and (37). We apply the Hamiltonian (Pontryagin) method. The constraint (36) is a simple overall resource constraint (frequently called "isoperimetric" constraint in the calculus of variations), so that the dual variable associated with it is a constant over time: call it λ. The constraints (37) (one for each individual) are differential equations; the associated dual variables are functions of time, say $\mu_i(t)$, and each satisfies a differential equation to be given below.

Form the so-called Hamiltonian obtained by adding the maximand to the constraints, each weighted by the corresponding dual variable.

$$H = \sum_i w_i \int_o^T P_i \, U_i(c_{it}) + \lambda e^{-rt}[x_i + \sum_i P_i(c_{it} + s_{it})]$$

$$- \sum_i \mu_i \ p_{it}(s_{it}, x_t) \, P_i. \tag{38}$$

(To obtain the last term, the equations (37) are written in the standard form, $\dot{P} = - p_{it} \, P_i$.) Then the optimum is characterized as follows: For each t, the flow variables, c_{it}, s_{it}, and x_t are chosen to maximize H. They are thus determined in terms of the state variables P_i and the dual variables. The dual variables μ_i (t) have to satisfy the differential equations,

$$\dot{\mu}_i = - H/ P_i. \tag{39}$$

Since the payoff is clearly not influenced by the values of P at time T, it can be shown that the corresponding dual variables must be zero there (the dual variable can be interpreted as the shadow price of the corresponding state variable, i.e., the increase in payoff associated with an infinitesimal increase in the value of P_i).

$$\mu_i(T) = 0 \tag{40}$$

Of course, by definition,

$$P_i(0) = 1. \tag{41}$$

Hence, the problem is to solve the differential equations (37) and (39) with the (awkward) boundary conditions (40) and (41). As the problem is set up, λ is still undetermined and must be chosen to make sure that (36) is satisfied.

We first maximize H with respect to the flow variables, c_{it}, s_{it}, and x_t.

$$w_i\ P_i\ U'_{it} + \lambda e^{-rt}\ P_i = 0, \tag{42}$$

$$\lambda e^{-rt}\ P_i = \mu_i\ (\partial p_i/\partial s_{it})\ P_i, \tag{43}$$

$$\partial e^{-rt} = \sum_i \mu_i\ (\partial p_i/\partial x_t)\ P_i. \tag{44}$$

Note that we can cancel P_i in (42) and (43).

$$w_i\ U'_{it} = -\lambda e^{-rt}, \tag{45}$$

$$\mu_i\ (\partial p_i/\partial s_{it}) = \lambda e^{-rt}\ . \tag{46}$$

The most striking implication comes from (46) in conjunction with (40). At t = T, the right-hand side is finite (actually, negative equation from (45) shows) while $\mu_i(T) = 0$. Hence, for t = T, it must be that $\partial p_i/\partial s_{it}$ is infinite. If, as before, we solve for s_{it} as a function of p_i (holding public expenditures on safety constant), we see that

$$\partial s_{it}/\partial p_{iT} = 0, \tag{47}$$

i.e., the willingness to pay for additional safety goes to zero at the end of one's life. By continuity, we can argue that the willingness to pay will decrease for old age, though I have not so far been able to prove that it is a monotonic decreasing function of time. (To be sure, the assumptions made so far are very general; but even experiments with much more specific functions have not yet led to this conclusion.)

In (44), we can divide through by λe^{-rt}, and then, in the i^{th} term on the right-hand side, replace it by the left-hand side of (46) to derive the same result as implied by (18) and (20):

$$\sum_i (\partial s_{it}/\partial p_i)\ (\partial p_i/\partial x) = 1. \tag{48}$$

Hence, the static results on the relative margins of public and private safety expenditures remain valid. Further study of the life-cycle analysis may yield stronger results.

For completeness, the differential equation (39) can be stated in explicit form as:

$$\dot{\mu}_i = - w_i\, U_{it} - \lambda e^{-rt}\, (c_{it} + s_{it}) + \mu_i\, p_i. \tag{49}$$

This still involves the welfare weight, w_i, which we seek to eliminate. Therefore, manipulate this equation further, as follows. First, replace λe^{-rt} in (49) from (45). Then define,

$$\nu_i = \mu_i/w_i;$$

and recall that w_i is a constant over time. Then divide through in (49) by w_i.

$$\begin{aligned}\dot{\nu}_i &= - U_{it} + U'_{it}\, (c_{it} + s_{it}) + \nu_i\, p_i \\ &= [U_{it} - U'_{it}\, (c_{it} + s_{it})] + \nu_i\, p_i.\end{aligned} \tag{50}$$

The bracketed term is a sort of consumer's surplus, hence this equation appears to have some meaning, as yet undefined.

Limitations of the Pareto criterion. Although the preceding analysis is obviously quite powerful, this approach has some significant limitations. First, if prices are not specified, it is not clear at what point the economy will equilibrate. Also, it is impossible to distinguish, for purposes of evaluating the level of social welfare, between various points of efficient equilibrium (i.e., the contract curve). Second, the possible efficient equilibria change as endowments change. For example, if the original endowment of some individuals is increased by a certain amount, and a like quantity is subtracted from other individuals, the set of efficient equilibria may be altered substantially.

A serious, but not fatal, deficiency of the Pareto criterion for evaluating social decisions involving low probability, high consequence occurrences is that it changes as knowledge and expectations change. If knowledge changes, expectations may change. Once expectations change the expected utility derived from any good or bundle of goods may also change. Assuming that individuals in the economy are risk-averse, as is implied by convex (to the origin) indifference curves, the preference orderings for any given set of expectations will be concave. However, if knowledge and expectations change, individuals will reevaluate the satisfaction derived from various goods. These revised expectations will change the utility associated with each consumption bundle and hence change the contract curve. Thus, at any particular point in time, an evaluation of a social decision with uncertainty might conclude that a decision is correct. Yet with additional information, obtained only with the passage of time, the conclusion might be that the decision is incorrect. If decisions are reversible, then this limitation of the Pareto criterion is not overwhelming. However, if decisions are irreversible, it may be that any original efficient equilibrium would impose substantial welfare losses over time.

There are other defects of the Pareto criterion. For example, it runs into conceptual as well as measurement difficulties if people attach value to ideologies or processes as well as to conventional commodities. It loses some of its appeal if we introduce certain plausible interdependencies among utility functions -- for example, degrees of malevolence, jealousy, or tastes for interfering with each other on the one hand, and on the other, empathy for others. 2/ Also, to approve this economic efficiency criterion without any reservations whatsoever requires a particular value judgment which many are unwilling to make. We simply do not believe it is right to permit sadist-masochist exchanges in which one person loses an eye or is assisted to commit suicide or sells himself into slavery. Moreover, Scitovsky re-raises troublesome questions about rationality. 3/ Finally, for those who believe Pareto optimality (loosely speaking, aggregate real income) is linked with welfare or happiness, several people including Scitovsky have presented arguments that reinforce one's intuitive doubts about strength of the long-run correlation.

Social Decisions and Processes

This section surveys the major components of the contract-based theories developed by Rawls and Buchanan. Their primary evaluative criterion for social decision-making is that, if the process of making the decision is just, then the decision, whatever it may be, is the socially correct one. In other words, it is not necessary to evaluate the "optimality" of the decision itself. The decision is believed to be optimal once it is determined whether the process is just. This complete refutation of "the ends justify the means" seems particularly appropriate for consideration in the post-Watergate morality.

Rawls' Theory of Justice. Rawls' theory is based on two principles of justice: 4/

First Principle -- Each person is to have an equal right to the most extensive total system of basic liberties compatible with a similar system of liberty for all.

Second Principle -- Social and economic inequalities are to be arranged so that they both are:

(a) to the greatest benefit of the least advantaged, consistent with the just savings principle, 5/ and

(b) attached to offices and positions open to all under conditions of fair equality of opportunity.

Rawls derives these "principles" from his definition of the "original position." The original position is populated by individuals who are all motivated by self-interest. Further, individuals are behind a "veil of ignorance" and do not know their endowment or status in any future state of the world. Rawls argues that combining the veil of ignorance and motivations of self-interest assures adoption of these two principles of justice, and will be ranked in lexical order. That is, no diminution of the first principle is allowed to obtain the second.

Criticism of Rawls' theory of justice are extensive. 6/ Significant limitations of Rawls' theory of justice include the artificial use of time, as required by the veil of ignorance, and the implied risk aversion or ignorance associated with adoption of the second principle of justice. The second principle of justice implies that an action is good if it does not decrease expectations of the most disadvantaged member of society. For example, the optimal social decision is the one that maximizes income of the poorest (minimum) individual. This "maximin" principle will be chosen if those in the original positions are infinitely risk averse. 7/

If it could be shown that adoption of Rawls' second principle is only consistent with infinite risk aversion, this would be a significant weakening of Rawls' argument for acceptance of the two principles of justice. However, Rawls claims that infinite risk aversion is simply consistent with the assumptions he makes concerning the original position. 8/ Rawls requires that individuals in the original position prefer the "well ordered" society. One component of a well ordered society is that any contract entered in the original position be one that each individual in the original position thinks he can "live with." Since, for Rawls, each individual in the original position is representative of himself and his future generations, this requires that each individual in the original position be able to "live with" the contract no matter what the future brings. If each individual in the original position could not live in a society (maintain his contract) if he or his future generations were sufficiently disadvantaged, then adoption of the maximin principle is consistent with the desire for a well ordered society, since a well ordered society requires that each individual be willing to abide by the contract developed in the original position.

Rawls tries to include time by having each person in the original position represent himself and all future generations. In this manner, Rawls attempts to derive principles of justice that will not change with the passage of time. This particular way of incorporating time means that Rawls' model remains static, and changes in knowledge cannot change the two principles of justice. At the same time, nothing seems to be repugnant about changes in the "principles of justice" over time since knowledge changes, provided the process of determining these changes is acceptable to society.

Another substantial criticism of Rawls' theory is that it implies a certain uniformity in the preferences of individuals in the original position. There cannot be substantial differences in their conceptions of justice and future possible states of the world or their perceptions of their effect on future possible states of the world.

Rawls argues for selection of the two principles of justice by contrasting the choice between his two principles and other possible rules such as total utility maximization, average utility maximization, etc. These alternatives, which are the choices considered by Rawls to be available to individuals in the original position, are not very dense. Other alternatives not unambiguously inferior to the two principles of justice may also exist. If some ambiguity does exist, then the only remaining way to maintain the choice of Rawls' two principles of justice is to argue on the basis of their "moral" worth, indicating that "right" men would necessarily prefer the two principles of justice. However, imposing some form of outside morality on their choices would upset Rawls' structure. Such an argument contradicts Rawls' emphasis that the two principles of justice are the only logical choices, given certain minimal axioms concerning individuals in the original position.

If one accepts Rawls' theory of justice, then the criteria for evaluating a social decision concerning a low probability, high consequence occurrence are relatively straightforward. First, does the social decision-making process maintain the first principle of justice? Or, does everyone have equal opportunity with respect to the social institution charged with making the decision, and are there other appropriate safeguards for this equality of opportunity during the decision-making process? Once this principle is fulfilled the question then becomes whether the social decision-making process and the decision are such that the most disadvantaged member of society does not suffer lowered expectations as a result of the decision.

Obviously, the most disadvantaged member might change after a decision is made. Rawls argues that this is an exceptional case due to what he terms a "chain connection". 9/ If the most disadvantaged member changes, Rawls' criteria imply that the expectations of the most disadvantaged, both before and after, must not decrease.

Evaluation of a social institution and process relative to the first principle of justice is qualitative. You either fulfill the first principle or you violate it. There are no degrees of fulfillment given the lexical order of the first and second principles. Measurement problems, which hinder application of either the average utility criterion or the Pareto criterion, remain in identifying the most disadvantaged member of society as well as determining whether that person's expectations have increased or decreased.

Buchanan -- The Limits of Liberty. Whereas Rawls effectively created a world where conflicts between individual preferences could not occur -- the original position -- Buchanan accepts the conflicting nature of individual's desires, and tries to determine whether these conflicts and their resolution imply that the state will grow beyond its "legitimate" limit. 10/ Buchanan begins from the basis of anarchy and describes how social institutions would evolve due to a recognition that a higher degree of Pareto optimality can be obtained through cooperation -- for example, a mutual agreement not to attack each other in a two-person society. Or, in a multi-person society, some subset of its members might agree to a mutual protection of their property, the endowment of which is a result of "anarchistic equilibrium."

Buchanan accepts the continuing revision of social contracts, in contrast to Rawls. As long as government does not exceed its legitimate limits, where the legitimate limits are defined by the Pareto criterion, any individually and freely chosen social contract is optimal since to conclude otherwise would imply that individuals were behaving irrationally. Once government goes beyond its limits, Buchanan offers no criteria for choosing among these inferior positions.

Buchanan's efforts seem more positive than normative. With little discussion, he accepts the Pareto criterion as the mechanism for defining suitable limits of government. Once these limits are defined, he demonstrates that individuals, maximizing their self-satisfaction, will create social institutions. In a world where social decision-making requires limited resources, these institutions will cross the acceptable limits defined by the Pareto criterion. Buchanan's primary focus is on showing why societies that begin with relatively few social institutions (in other words, the United States) inevitably end up with too many social institutions, and the Pareto efficiency of the society is hindered. In the context of this discussion, though, Buchanan's views provide an effective means of appraising criteria derived from Rawls' theory.

Summary

This chapter has discussed rather different criteria for evaluating social decisions. The next chapter will argue for a "mixed" approach to evaluating social decisions involving low probability, high consequence occurrences. The mixed approach is composed of (1) the dominant ethic of present day evaluations: an act or a process is good if its consequences are independently demonstrated to be good, and (2) the contract-based theory and principle of ethics implied by Rawls and Buchanan: the good is that which emerges from a proper procedure.

The argument for this mixed approach is based in substantial part upon the lack of knowledge and associated uncertainty that characterizes social decisions involving low probability, high consequence occurrences. Although an evaluation can estimate the expected net benefits of a decision, this present estimate of net benefits is obviously not necessarily equal to the actual benefits that will be incurred. If possible actual outcomes are sufficiently diverse -- if there is a great deal of uncertainty -- then conflicting estimates of the expected net benefits are likely. It may be impossible to convince each member of society that any particular estimate, and decision, is superior to all alternatives. Thus, in addition to generating good decisions, it is also necessary that the social decision-making process lessen or resolve conflicts, in order that the final decision will be accepted and, therefore, will be implementable.

Another important reason for the mixed approach recommended here is that social decisions involving low probability, high consequence occurrences impose risks upon members of present and future generations. Imposition of these risks appropriates a portion of the property rights of individuals in present and future generations, since they are no longer able to choose to reduce the risk they bear below the new, higher minimum established by the social decision. Definition of property rights has historically been charged to social institutions. Validity of these definitions has been evaluated in terms of the quality of the process used to develop them as well as the justice of the definitions. For these reasons a "proper process" is important.

Notes to Chapter 3

1. See Scott Gordon, "The New Contractarians". Journal of Political Economy (June, 1976), pp. 573-590.

2. Feeling for others that transcends simple market values manifests itself in many ways and has long been recognized as a force by both economists and noneconomists alike. A familiar example of a noneconomic statement of such feelings is the following: "No man is an Iland, intire of it selfe; every man is a peece of the Continent, a part of the maine; if a Clod bee washed away by the Sea, Europe is the lesse, as well as if a Promontorie were, as well as if a Mannor of thy friends or of thine owne were; any mans death diminishes me, because I am involved in Mankinde; And therefore never send to know for whom the bell tolls; It tolls for thee." John Donne.

3. Tibor Scitovsky, The Joyless Economy (New York: Oxford University Press, 1976).

4. John Rawls, A Theory of Justice (Cambridge, Mass.: Belkamp, 1971), p. 302.

5. The just savings principle requires that each member of the original position represent family lines, with ties of sentiment between successive generations. These ties are then the basis for determining the criteria for justice between generations, for example, a specified minimum rate of savings. See Rawls, A Theory of Justice, pp. 291-93.

6. See Gordon, "The Contractarians"; Sidney S. Alexander, "Social Evaluation Through National Choice," Quarterly Journal of Economics (November 1, 1974), pp. 625-32, and R. A. Musgrave, "Maximum, Uncertainty, and the Leisure Tradeoffs," Quarterly Journal of Economics (November 1974), pp. 625-32.

7. Musgrave, "Maximum, Uncertainty and Leisure Tradeoff".

8. John Rawls, "Reply," Quarterly Journal of Economics (November 1974), pp. 633-55.

9. Rawls, A Theory of Justice, pp. 81-83.

10. James M. Buchanan, The Limits of Liberty: Between Anarchy and Leviathan (Chicago: University of Chicago Press, 1975).

4. Criteria For Evaluating Social Decision Processes

Characteristics that distinguish environmental risk problems were described in Chapter 2. Many of these characteristics can give rise to severe contention among various members of society.

Limited knowledge, for instance, may make any general agreement on expected benefits and costs impossible. Because the estimated probabilities are so low, and typically have no empirical basis, there is often a wide range of estimates, even among knowledgeable and informed scientists. This range of uncertainty in turn leads to large differences concerning expected costs. For example, consider a high consequence outcome with a cost of $500 billion ($\$5 \times 10^{11}$) if it occurs. Also, assume that the plausible low probability estimates range from 10^{-11} to 10^{-6}. Since the consequence is so costly if it occurs, two technical experts who believe that the appropriate low probability estimate is at either extreme of the "possible" range have implied expected costs ranging from $5 (trivial) to $500,000 (substantial).

Many situations that give rise to environmental risk do not represent technological breakthroughs with extremely high economic payoffs. Rather, the expected net benefits are often in a range comparable to other investments that do not involve any known environmental risk. This makes uncertainty concerning the high consequence outcome critical to evaluation of the project. To illustrate, assume that the certain costs of the project are $1,000,000 and certain revenues are $1,100,000. Known revenues and costs imply that the project is beneficial. However, if cost of the consequence, in case a bad event occurs, is agreed to be $500 billion, the lowest low probability (10^{-11}) implies pursuing the project while the highest low probability (10^{-6}) implies a substantial expected loss from pursuing the project. In this example an optimal decision depends critically upon this expected cost item.

If uncertainty concerning the probability estimate is coupled with uncertainty about the expected cost of a bad occurrence, the potential for significant differences of opinion increases. For many environmental risk situations, some people will feel they are "losers" no matter what decision is made.

Yet another source of potential discord and contention arises from the fact that decisions involving low probability, high consequence occurrences often have implications for future generations. It is impossible to account perfectly for the preferences of future generations, since their prefer-

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ences are not known, but a well-ordered society (to use Rawls' phrase) requires some explicit recognition of these future generations and their possible state of affairs.

Economic efficiency is, of course, also important. Under certain conditions, a free market structure permits the greatest value to be obtained from a given set of resources. A benefit-risk-cost analysis applies values observed in the market to develop an estimate of the net return associated with a project. A "complete" benefit-risk-cost analysis will in theory enable a social decision-maker to make the optimal choice. Obviously a benefit-risk-cost analysis is never complete. In many instances, though, including many problems of classical environmental pollution, it provides a close enough approximation to serve as the principle basis for the decision process. However, characteristics of low probability, high consequence occurrences, as outlined in Chapter 2, coupled with difficulties of applying the Pareto criterion, described in Chapter 3, make it impossible to maintain that a benefit-risk-cost analysis can imbed an acceptable consideration of future generations as well as resolve contention over widely varying estimates by "experts" on what are often highly charged emotional issues.

Economically efficient solutions that seriously undermine the social order are not socially optimal in a broader perspective. Economic efficiency must be pursued within the constraint of social acceptability. There are too many caveats to rely solely on a benefit-risk-cost analysis, or, for that matter, Rawls' maximin criterion. A process is required that will make an incorrect decision with only a low probability while minimizing contention. Such an approach will necessarily include components of a "good" benefit-risk-cost analysis. It will also include some components of maximin and other criteria required to convey the belief that affected individuals have had their preferences and desires considered. Thus, a proper evaluation of social decision processes involving low probability, high consequence occurrences requires a mixed set of criteria.

Outcome and Process Evaluation

In order to develop a set of criteria, we have combined requirements for economic efficiency with requirements for an acceptable social decision process. These criteria can be used to evaluate legislative hearings and deliberations, proceedings of the National Academy of Science, hearings and proceedings held under the Administrative Practices Act, legal proceedings in the courts, and proceedings before any new tribunal such as a Science Court, should it ever be established.

The applicability of existing institutions for handling problems of environmental risk are being called increasingly into question. It is widely recognized, for instance, that the legal system pursues the truth within a very special framework. The objective is to limit the chance of a false conviction, on grounds that it is better to free many guilty people rather than convict one innocent person. Under these circumstances the truth is occasionally secondary to the process -- for instance, evidence obtained illegally is not admissable, regardless of how firm it is or how much light it might shed on the guilt of the accused. This does not mean that the legal system does not search for the truth, but simply that truth is sought only within constraints imposed by the process. Some characteristics of the process are valuable enough to warrant decreased accuracy. For example, the process guards rights that society has assigned to individual liberty. Also, it explicitly considers the bases of contention so that opposing parties are generally willing to accept the decision.

The legal system evolved as a means of resolving past occurrences, either crimes that had been committed or civil disputes involving some prior incident such as breach of contract or injury of one party by another. While the legal process can perhaps be improved marginally, it seems generally sufficient for its present purposes. If it makes a mistake, the outcome does not involve unusually high cost to society. As long as the legal system maintains a certain rate of accuracy, no argument is seriously accepted that the legal system should be changed because it does not always result in an accurate decision.

Throughout its long evolution, however, the legal system was never intended to be a future-oriented decision process, and many are beginning to question whether the procedures and biases which are so deeply rooted in the established legal process represent the best choices for making future-oriented decisions. As noted previously, there are two types of error in a criminal case: (1) falsely convicting an innocent person, and (2) failing to convict a guilty person. Decisions involving environmental risk also have two types of possible error: (1) falsely predicting a catastrophic outcome from a relatively safe or harmless situation, and (2) failing to predict a catastrophic outcome. The criminal process seeks to minimize the first type of error, and many feel that the social decision process should be designed to minimize the second type of error. That is, it should err in the direction of rejecting projects that are not, in fact, all that risky in order to avoid the mistake of accepting projects that are, in fact, risky. In other words, mistakes should have a very low probability of occurrence. Since there may be disagreement over the correct decision, an acceptable process is necessary in order that the decision, whatever it may be, is accepted. Table 1 summarizes the primary source for each of the evaluation criteria developed for this project. As indicated there, the economic, maximin, and contract approaches have all been used to derive these criteria. The description of each criterion also includes some discussion of the source.

Evaluation Criteria

The criteria that should be fulfilled by a process making social decisions involving low probability, high consequence occurrences include:

1. Are parties who incur the present costs adequately represented?

2. Are the parties who incur the present benefits represented? Criteria 1 and 2 insure the present parties to the decision come together. These criteria are necessary for an optimal trading arrangement as defined by Pareto. They are also necessary requirements for acceptance of a decision

TABLE 1

Proposed Evaluation Criteria & Their Derivation

Criterion	Economic (Pareto)	Maximin (Rawls)	Contract (Buchanan)
1.	x	x	x
2.	x	x	x
3.		x	
4.	x	x	x
5.		x	
6. a.		x	x
b.	x		
c.		x	
d.	x		
e.		x	
f.	x		
7.		x	x
8.	x		

that comes out of the process, particularly if the distribution of benefits differs from the distribution of costs.

3. Are interests of the future generations suitably considered? Social decisions that impose benefits, costs, and risks over a long period of time make it necessary to consider future generations, yet consideration is necessarily limited by our lack of knowledge concerning future states of the world and future preferencs. At a minimum, however, it is necessary to describe, as accurately as possible, possible impacts on future generations. Once this description is obtained, members of society can, if they choose, attempt to represent both themselves and future generations as in Rawls' original position. Criterion (3) goes beyond the usual role of the social discount rate in the benefit-risk-cost analysis. Interdependence of risks over time, coupled with considerations of irreversibility and uncertainty concerning future preferences generally make it impossible to consider adequately future generations through a social discount rate.

4. Are distributional aspects considered systematically? Distributional aspects of the social decision may be significant. If they are, compensation (through the tax system, perhaps) is necessary. At a minimum, groups who gain or lose should be identified for each alternative decision. This criterion is of importance to acceptance more than optimality. A social decision that makes the rich better off without imposing any costs upon the poor is an economically efficient action. Acceptance of this social decision may nevertheless require that some of the additional income be redistributed to the lower classes, in order to maintain stability of society, especially if there is some uncertainty about the distributional aspects. Finally, Rawls' maximin criterion requires that the least advantaged (e.g., poorest) not be injured by the decision.

5. Are social decision makers "unbiased" and open? In a free market prices are unbiased in that they are not influenced by any one individual. A particular preference or opinion influences prices only if held by significant numbers of individuals. A similar property is desired of decision-makers since they are effectively allocating resources among competing claims. This is the "unbiased" property of the decision-maker and is necessary for an optimal decision. Also, the decision is more likely to be accepted by losers if the decision-makers are perceived to be unbiased. The other characteristic is that the decision-maker be "open". The decision process for low probability, high consequence occurrences must not preclude intermediate decisions. If the process indicates sufficient uncertainty, the decision-maker must be able to make limited choices, i.e., to keep his options open. If uncertain as to the impact of a social decision, it may be wise to incur a higher expected present cost by limiting the program, while more accurate information is developed through experimentation and observation of the limited program.

6. Development of knowledge concerning the effect of possible alternative decisions:

a. Do views that appear to come from reasonable sources receive -- or appear to receive -- "equal time and treatment"?

b. Are all significant differences considering quality of knowledge included?

c. Are gaps in knowledge identified?
d. Are procedures for collecting knowledge of the area efficient?
e. Are plausible consequences for the worst contingency spelled out?
f. Are alternatives suitably considered? That is, does the process explicitly recognize the uncertainty and lack of knowledge about pertinent alternatives or possibilities?

Criterion (6) is the means of evaluating the effectiveness of the process at eliciting the available knowledge, defining the areas of uncertainty, and defining the possible alternative decisions. Obviously, it is necessary that a complete benefit-risk-cost analysis fulfill this criterion. In order to make an optimal choice, in any sense, it is necessary that we determine what is known and not known about possible states of the world. Once this knowledge is obtained, it is necessary to define the possible alternative decisions since optimality of any one decision or mix of decisions will be dependent upon our knowledge.

7. Is information given to individuals who are at risk? Those who will experience an increase in their level of involuntary risk should obviously be informed, since their property rights are being altered. This criterion for writing a new contract is required by both Rawls and Buchanan. In order to inform these individuals it is necessary that knowledge developed by the process be translated into "lay" terms, including succinct presentation of the state of disagreement, especially if scientists reach quite different judgments. Fulfillment of this criterion should increase acceptance of the decision. While not required by the criterion of Pareto efficiency, in practice it might also increase the probability of an optimal decision from the process.

8. Can a decision change if significant new information is obtained? This final criterion is particularly sensitive since frequent change is undesirable due to possibly high transition costs. Yet, unlike legal proceedings, the decision process must not rely too heavily on historical precedent. This criterion recognizes the dynamic implications of many social decisions involving low probability, high consequence occurrences. When an individual decides upon a path of action over time, he is free to change his path if his knowledge and expectations change. However, the individual will not change his actions with every change in his knowledge and expectations. Some changes will not be sufficient to warrant incurring the costs of change. Optimality of the social decision over time requires that the decision process must have an element that defines circumstances for reconsidering a decision.

Obviously, each of these criteria is subject to dispute. Also, it is only possible to formulate such criteria in a finite number of pages by alluding to words like good, adequate and appropriate. The criteria are derived from a desire to see correct social decisions made and accepted. Some of these criteria are verbal adaptations of the steps necessary in a good benefit-risk-cost analysis. A verbal adaptation is necessary since our lack of knowledge concerning social decisions involving low probability, high consequence occurrences insures that there will be disagreement about some of the components. Other criteria are based primarily on a desire that decisions of a "good" process be acceptable. Thus, the process has value in terms of both optimality of its decisions and acceptability by the affected individuals.

These criteria avoid both extremes: Pareto efficiency implies that a process is good if it gives consequences that are independently demonstrated to be good. The ethics implied by Rawls and Buchanan, at the other extreme, are that the good is that which emerges from a proper procedure. If a process meets the eight proposed criteria, then it fulfills both principles of ethics. Some of the criteria insure that the decision will be optimal except in a low number of cases. Other criteria insure that the process and its decision will be acceptable to affected individuals because the process is, in certain specified senses, proper.

Conclusion

The problems facing a benefit-risk-cost analysis of low probability, high consequence occurrence are so many as to make any analysis subject to wide dispute. Certainly, benefit-risk-cost analyses of pesticides or nuclear power are always arguable. Controversy seems to center on whether we are willing to assume present risks and whether we are willing to impose risks on future generations.

If a decision tests the limits of our knowledge sufficiently, or if the risk is severe enough, we will not accept the market process or its surrogate (benefit-risk-cost analysis) without other procedures associated with social institutions. The reasons have been discussed throughout this paper. The conclusion is that a process for making social decisions involving low probability, high consequence occurrences should fulfill certain criteria that imply a high probability of an optimal decision as well as acceptance of the decision by the affected parties.

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PART II

CASE STUDY OF CHLORDANE/HEPTACHLOR

5. Introduction

This case study is concerned with social decisions about situations involving low-probability, high-consequence events. When they occur, such events are usually referred to as "disasters" or "catastrophes." Low-probability, high-consequence events are sometimes caused by natural occurrences, such as earthquakes, floods or tidal waves, but history has also witnessed high-consequence events not caused by nature. A few well-known examples are the Chicago Fire, the Texas City explosion, the underwater oil blowout in the Santa Barbara channel, and the numerous birth defects caused by thalidomide. Some of these disasters might have been avoided had someone, or some authority, taken timely action.

Any modern, high-technology society is susceptible to a wide variety of low-probability, high-consequence events: (1) air crashes of fully-loaded giant aircraft; (2) the release of large quantities of poisonous gas near a population center while being transported; (3) major explosions or oil-spills from giant supertankers while in harbors of major cities; or (4) nuclear reactor accidents that result in large-scale release of radioactive materials. Government decisions have been and are being made in all these areas, but this does not necessarily mean the decisions are correct, or that the social decision process used to determine our choices is as good as it could be.

This is a case study of the existing collective decision making process in one area of environmental concern: namely, low-probability high-consequence events that may arise from the use of pesticides. All chemical pesticides contain biologically active ingredients, and are by design, toxic to some living organisms. It has long been recognized that this toxicity can pose an inherent threat to humans who are overexposed to the chemical. Given a high enough level of exposure, people will suffer adverse toxic effects with high probability.

The key concern of this case study is not with the risk of direct toxicity, but with a different kind of risk posed by chemical pesticides -- the possibility that the introduction and use of some pesticides may cause widespread cancer, thereby shortening the lives of thousands, or even tens of thousands of people. On the basis of what is known about the causes of cancer, the probability that chemical pesticides might be the direct cause of so many deaths does not appear to be high. At the same time, it is now known that residues from some pesticides do find their way into our food supply. If these residues can and possibly do cause cancer in some people, then we are faced with a low-probability, high-consequence situation. The effects of carcinogenic pesticide residues may not be as dramatic as other disasters and catastrophes, but the results are equally serious, if not more so. This case study is therefore focused on this situation, the problems that it raises,

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and the decision making procedures and public policies appropriate to controlling it.

The first pesticide to be widely questioned and challenged because of its environmental effects was DDT. Attacks against DDT increased in intensity during the 1960's and, after a widely-publicized proceeding, culminated in cancellation of registration on June 14, 1972. 1/ The possibility of DDT residue finding its way into food, and the possibility that such residue might be carcinogenic, were but two of the many adverse effects ascribed to DDT. It was alleged to have a large number of adverse environmental effects, including harm to fish and wildlife, especially birds. The findings of fact, both at the time of the cancellation hearing and in a subsequent follow-up study by EPA, 2/ indicate that DDT did indeed cause a large number of environmental problems that justified the cancellation of its registration.

By the time the cancellation order was finally issued and implemented, it was widely known that the use of DDT was declining because many pests were developing a resistance to DDT. Because the cancellation decision involved so many factors, and because use might well have continued to drop off even without regulatory action, DDT does not provide a clear-cut example for dealing with risks posed by pesticides that are possibly carcinogenic. 3/ The facts and evidence developed at the DDT hearing did, however, indirectly raise important questions concerning other pesticides, especially chlorinated hydrocarbons such as aldrin, dieldrin, chlordane and heptachlor. All of these pesticides have now been the subject of adversary regulatory proceedings. We thus have available for review extensive, documented public records of the current decision-making process in operation.

The study deals with the two pesticides chlordane and heptachlor, because (a) they have been the focus of an extensive regulatory decision-making process by the Environmental Protection Agency, and (b) the principal basis for challenging the registration of these two pesticides was their carcinogenicity. Chlordane and heptachlor, as well as the other chlorinated hydrocarbons, are effective against a broad range of pests and persist in the environment for several years after application. These characteristics make them highly desirable products for pest control, and have resulted in their widespread application to many crops and millions of acres of land.

Chapter 6 surveys the development of federal pesticide regulation especially as it relates to cancer and other serious long-term side effects. This survey includes a description of the current decision-making process as embodied in existing legislation and the regulations of executive agencies. At the heart of this process is a set of quasi-judicial adversary proceedings whose basic philosophy has been unchanged since enactment of key pesticide legislation in 1972, even though legislative amendments (1975) and new administrative regulations within the Environmental Protection Agency (1976) have changed some of the detailed triggering and review mechanisms. 4/

Chapter 7 takes a closer look at these adversary proceedings and their administrative setting in the case of chlordane and heptachlor. This is a major proceeding with at least one significant phase (suspension hearings and decision) completed at the time this study was undertaken. The chlordane/heptachlor case represents a procedural divide: it was the last to be initiated under the administrative rules preceding the 1976 changes, and as such provides the best test case available for discussing differences which the new rules are likely to make with regard to the effectiveness of the decision-making-process.

Chapter 8 contains an extensive analysis and discussion of the theoretical issues that arise in connection with decisions involving the risk of cancer from pesticides. Materials from preceding chapters are used to place these theoretical issues within the context of the current decision-making process.

Chapter 9 examines the pesticide decision-making process in the broader setting of various institutional arrangements designed to gather, present and weigh scientific evidence on controversial issues. This chapter puts the existing decision process into a perspective that spans both existing and proposed alternative institutions.

The concluding chapter, (Chapter 10), contains an evaluation of the current decision process used for pesticide products. The criteria for this evaluation are those developed in Part I of this study.

Notes to Chapter 5

1. The DDT cancellation hearing lasted approximately seven months. See U.S. Environmental Protection Agency, Environmental Facts - DDT and the Environment (Washington, D.C.: Environmental Protection Agency July, 1974).

2. U.S. Environmental Protection Agency. DDT: A Review of Scientific and Economic Aspects of the Decision to Ban its Use as a Pesticide. (Washington, D.C.: Environmental Protection Agency, July, 1975) (EPA-540/1-75.022).

3. Carcinogenicity is not the only low-probability, high-consequence occurrence that can result from pesticides. Catastrophic non-cancer impacts are also possible. For example, certain ingredients or impurities in herbicides may destroy the viability of life sustaining support systems or result in mass birth defects through mutagenic or teratogenic effects.

4. Detailed citations will be found in Chapter 6.

6. Review of Federal Pesticide Regulation

This chapter traces the historical development of the legislative and regulatory framework within which decisions concerning chlordane and heptachlor have been made. The purpose of this review is to identify issues pertinent to decision-making about low-probability, high-consequence events, and to put the subsequent discussion about chlordane and heptachlor into context.

Federal pesticide regulation is viewed here as occurring in several waves that originate at different times, and are associated with the emergence and disposition of distinct issues. Each wave has several phases, drawn out over years or decades, with different phases of separate waves often overlapping in time. The principal phases are:

1. Legislation, as enacted by Congress. This phase includes formation of public awareness concerning issues, which necessarily precedes legislation, together with the political process that accompanies enactment of the legislation.

2. Regulation, which follows the legislative phase. For pesticides this is the registration process, including the labelling, application and record-keeping associated with the use of pesticides, plus the continuing information gathering and monitoring process.

3. Adversary proceedings, including all suspension and cancellation proceedings before administrative law judges, procedures governing such proceedings, and appeals to the federal courts.

Subsequent sections of this chapter review each of these phases as it relates to the problem of low-probability, high-consequence results of pesticide use. Special attention is given to the possibility that thousands, or even tens of thousands of people may eventually die from cancer as a result of consuming (1) chemically-treated agricultural products containing residues of carcinogenic pesticides; or (2) other food products -- such as fish -- into which such pesticide residues find their way via watersheds and the ecological food chain.

Extensive public concern with the issue of such risks is relatively recent. Although Congress has now enacted legislation aimed at coping with low-probability, high-consequence events, and although it is readily apparent

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that government as a whole is taking more action than in the past, serious concerns persist. It is not clear that the right kind of actions have been taken, that the actions being taken are adequate to the problems, or that the entire process is approaching anything that might be called socially optimal. Numerous scientists have expressed such serious doubts and concern about the existing process that one possible alternative, known as the Science Court, is in advanced stages of formulation. Further discussion of alternative decision processes is deferred until Chapters 9 and 10.

Federal Legislation Dealing with Pesticides

Early History. Federal involvement in the regulation of pesticides began in 1910 with the adoption of the Federal Insecticide Act. 1/ This Act was designed to prevent the manufacture, sale or transportation of adulterated or misbranded insecticides, and was administered by the Department of Agriculture. This Act was intended primarily to protect farmers and other pesticide purchasers who could not individually afford to analyze chemical products in order to protect themselves from fraud. Such fraud would have reduced the productivity of farms, as well as the income of farmers. These potential outcomes were directly counter to the objectives and concerns of the Department of Agriculture, so it was designated by this legislation as the agency to oversee the prescribed regulation of pesticides. This early Act recognized pesticides as toxic substances, but was chiefly aimed at providing accurate information to purchasers, and placed almost full reliance on the principle of caveat emptor for the subsequent safety and protection of persons using these substances. Registration of existing pesticides was not required by this 1910 Act.

The next significant legislative action was in 1938, when Congress revised the Food, Drug and Cosmetic Act. 2/ Among other things, this Act charged the Food and Drug Administration (FDA) with the responsibility for keeping poisonous insecticides out of food products. Significantly, this law did not require manufacturers to establish the safety of food additives in advance of actual usage. Instead, it was left up to the FDA to discover the use of additives, and make the tests to prove them "poisonous or deleterious" to the satisfaction of the court when action was required to remove them from the market. This 1938 law included provisions for setting tolerances for poisonous ingredients, when justifiable, but the procedure was cumbersome, time-consuming, and expensive.

Enactment of FIFRA. Following World War II, Congress enacted the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) in 1947. 3/ This Act extended the 1910 Federal Insecticide Act to include rodenticides and herbicides, and required premarketing registration of products to be shipped in interstate commerce for the first time. This Act charged that a complete copy of the label and a statement of all claims to be made for the material be submitted to the Secretary of Agriculture and approved before the material could be registered for sale in interstate commerce. Like the 1910 Act, the 1947 FIFRA legislation was, above all, concerned with protecting consumers from misbranded products. And, like the 1938 Food, Drug and Cosmetic Act, it focused on direct toxic effects and gave no specific attention to indirect or long-delayed effects such as carcinogenicity. Chlordane and heptachlor were initially registered under the 1947 FIFRA legislation. The authority to deny registration applications was not provided until 1964. 4/

By 1951, a flood of new chemicals, together with growing concern over the increasing use of chemicals in food products, led the House to appoint a Select Committee to investigate the use of chemicals in food and cosmetics. In 1952, the majority report of this Committee (known as the Delaney Committee) indicated a belief that existing laws were inadequate. After some delay, Congress amended the Federal Food, Drug and Cosmetic Act to include the Pesticides Chemicals Amendment in 1954. 5/ Like previous legislation, this law focused on the toxicity of pesticides and the procedures for determining tolerance levels. Although procedures for establishing tolerances were administered by the Department of Health, Education and Welfare (HEW), the Department of Agriculture was required to express an opinion as to whether proposed tolerances were reasonable and whether residues were likely to result from proposed patterns of use.

The Delaney Clause on Carcinogens. Public concern over chemicals in the food supply continued to mount, and in 1958 Congress enacted the Food Additive Amendment to the Federal Food, Drug and Cosmetic Act. 6/ This amendment established principles, processes, and appeals procedures for regulatory actions by HEW prescribing safe conditions of use for food additives. This legislation defined a food additive as any substance the use of which may reasonably be expected to result directly or indirectly in its becoming a component of or otherwise changing the characteristics of any food. However, *the law specifically excluded pesticide chemicals, pesticide residues on crops* (raw agricultural commodities) *and pesticide residues in processed food when such residues result from legal uses of pesticides on crops*. Pesticides continued to be regulated under the 1954 Pesticide Chemicals Amendment,

Although the 1958 Food Additives Amendment intentionally excluded pesticides, it contained a clause on carcinogens which is highly significant for this study. This provision, known generally as the "Delaney Clause", stipulates that *no additive shall be deemed safe if it is found to induce cancer when ingested by man or animals*.

The 1958 Food Additives Amendment represents the first legislation dealing directly with carcinogens in food products. It does not permit any consideration of the level of risk involved, nor does it permit any consideration of potential benefits from use of the additive in question. The FDA must ban any additive found to be the least bit carcinogenic. While the Delaney Clause may not be representative of the stance that all legislative bodies will assume with regard to such problems, it is an indication that when elected bodies directly confront such issues, they tend to opt for decisions involving minimum risk, regardless of other potential benefits or consequences.

The Delaney Clause is not part of any legislation that pertains directly to pesticides. However, standards used in adversary proceedings involving pesticides appear to be gravitating towards this position. (See Chapter 7 for further discussion of this development.)

Current legislation concerning pesticides. 7/ During the 1960's the environmental movement gathered momentum and became widespread throughout the United States. By 1970, public concern with environmental matters resulted in the establishment of the Environmental Protection Agency (EPA). 8/ In 1972, Congress enacted major amendments to the FIFRA of 1947 through the Federal Environmental Pesticide Control Act (FEPCA). 9/ These amendments made EPA (instead of the Department of Agriculture) responsible for administering FIFRA, and it required that all pesticides sold in the United States -- not just those entering interstate commerce -- be federally registered. Registration under standards of FEPCA is required for all pesticides already in use as well as new ones.

Reregistration of existing pesticides with EPA was to be completed by October, 1977. Under this act pesticides are to be classified for either general or restricted use. For the first time, pesticide users are made responsible for following the approved direction -- that is, applicators who fail to follow directions, or who use a pesticide for an unauthorized purpose, are guilty of a misdemeanor. Prior to 1972 "authorized" uses were essentially advisory in nature, and unauthorized uses were not prohibited in any meaningful sense. In short, FEPCA transformed the earlier FIFRA from a labelling law into a comprehensive regulatory statute.

Most significantly for the purpose of studying public approaches to low-probability, high-consequence outcomes, FEPCA gave the Administrator of EPA the authority to reject an application for registration altogether, or to restrict, suspend, or cancel the registration of any pesticide that may have "unreasonable adverse effects on the environment." This is defined under the law to mean "any unreasonable risk to man or the environment, taking into account the economic, social, and environmental costs and benefits of the use of any pesticide" (emphasis added). 10/ On first reading, this legislative standard appears less restrictive than the Delaney Clause in the Food, Drug and Cosmetic Act, since it calls for -- or at least permits -- a weighing of all risks, costs and benefits, and since considerable evidence is entered into the record during a cancellation or suspension hearing. Yet EPA regulations and court precedents both appear to be moving toward the position that finding a pesticide to be carcinogenic to animals or man constitutes prima facie evidence of an unreasonable adverse effect.

In 1975 the basic FEPCA legislation was amended 11/ to provide for minor changes, which made the decision process of EPA more open to outside inspection and consultation. These amendments require the EPA Administrator to give notice to and consult with the Secretary of Agriculture on the cancellation or reclassification of any pesticide prior to publication of notices of intent. Further, Congress specifically required EPA to consider the impact of such actions on "production and prices of agricultural commodities, retail food prices, and otherwise on the agricultural economy." 12/ Likewise, regulations concerning administrative procedures before EPA, in both their proposed and final forms, require notice to and consultation with the Secretary of Agriculture.

The 1975 amendments also created a Scientific Advisory Panel to "comment as to the impact on health and the environment" of proposed specific actions and general regulations. Notice to and consultation with this panel is mandated on the same terms as those specified for the Secretary of Agriculture. 13/

The regulatory decision process created by FEPCA involves a number of stages which, for purposes of discussion, we will refer to in this study as a sequential decision making process. Briefly, the various stages are as follows.

1. Registration or reregistration. This is the initial decision applying to pesticides not already registered and to all pesticides registered prior to the enactment of FEPCA in 1972. It includes the following clusters of preliminary or subsidiary decisions:

   a. Issuance of regulations governing the type and amount of data required to be submitted in order to register or re-register any pesticide. Applicants for registration must submit any information requested by the agency.

   b. For individual pesticides, processing and consideration of the data and information submitted in response to the registration or re-registration requirements, leading up to the key decision whether to register or re-register the pesticide, whether to do so for general or restricted use, and what, if any, restrictions to impose.

   c. Prior to the EPA Administrator's final decision on registration and classification, the Agency issues either a "Rebuttable Presumption Against Registration" (RPAR), in the case of suspect products, or an intent to register, in the case of apparently acceptable products. Publication of these notices in the Federal Register provides both registrants and interested third parties with an opportunity to submit materials bearing on each case.

2. Monitoring. This involves a series of administrative decisions within the Environmental Protection Administration, relating to the organization of its programs and coordination with monitoring programs implemented by other agencies. The decisions concern information gathering, organization, and evaluation for pesticides already registered and in use. These decisions underlie all further decisions initiated by the Agency involving outside parties.

3. Issuance of a Notice of Intent to Cancel registration. This decision results from the above monitoring process, either under the Agency's own initiative, or in

response to the intervention of third parties acting on behalf of the alleged public interest. Unless the parties concerned acquiesce in the action, this decision triggers administrative law proceedings. A closely related variant provided for by the law is a decision by the Administrator to call a hearing to assist him in deciding on the cancellation question, without issuing a notice of intent to cancel. This provides a forum for the submission and detailed clarification of evidence without placing as much of a stigma on a product as a formal notice of intent to cancel.

4. Issuance of a Notice of Intent to Suspend registration. This decision involves considerations similar to those noted under (3) above, and is designed for situations of "imminent hazard" pending the outcome of formal cancellation proceedings. A notice of intent to suspend must be preceded or accompanied by issuance of a formal notice of intent to cancel.

5. Suspension of registration. This decision applies to some or all uses of a pesticide. Suspension is a temporary measure, pending the outcome of formal cancellation proceedings. Suspension of a registration may be preceded by an "expedited" administrative law proceeding, or the Administrator may, at his option, suspend registration without any formal hearing.

6. Cancellation of registration. This decision permanently prohibits some or all of the uses for which a pesticide has been registered. An administrative law proceeding and review by the Administrator of the Agency are required, if requested by an affected party.

Beyond step 6 above, parties who wish to take exception to an administrative decision may appeal to the federal courts.

Stages 1 and 2 were described in the introduction to this chapter as "regulation," and stages 3 through 6 collectively fall under "adversary proceedings". The following sections of this chapter describe in more detail how each stage functions. The analysis of theoretical issues concerning this sequential decision process is postponed until Chapter 8.

Administrative Regulation of Pesticides

Under the 1972 FEPCA legislation, all pesticides used in the past had to be reregistered by October, 1977, in order to be legally marketed after that date. Rules and criteria governing the registration, reregistration, and classification procedures for pesticides were published in the Federal Register on July 3, 1975 (pp. 28242-28286). Registration and reregistration of individual pesticides is also underway as an ongoing activity.

Of the 35,000 pesticides used in the past, some are no longer in use or are no longer commercially important. Nevertheless, EPA's reregistration workload has been staggering. In order to facilitate processing such a large number of applications, the Office of Pesticide Programs (OPP) within EPA reviews the initial information that registrants submit (which now includes data and results of animal tests pertaining to carcinogenicity), and then publishes in the Federal Register either (1) a Notice of Intent to Register, in the case of products which it finds acceptable; or (2) a Rebuttal Presumption Against Registration (RPAR), in the case of suspect products. Any interested party wishing to reverse EPA's tentative decision has an opportunity at this point to submit materials bearing on the case. This completes the first phase. However, as noted by Phillip L. Spector in a study of EPA pesticide regulation: 14/

> Under the statute, registration of a pesticide does not end the inquiry concerning its environmental safety. The registrant is under a continuing statutory duty to submit any information it obtains concerning unreasonable adverse effects. Other interested persons may provide EPA with relevant information, and the Agency's own scientists frequently review the available literature and conduct research on registered products and their chemical constituents. Hence there are several sources from which the Administrator may obtain new information that changes his previous assessment, made at the time of registration, that the benefits of a pesticide's use outweighed its risks. Moreover, a change in Administrators or in societal values may lead to a fresh evaluation of the seriousness that should be ascribed to predicted risks.

Monitoring program. Follwing the initial cluser of decisions involving registration and reregistration, the second stage moves on to monitoring activities. This includes information-gathering activities by EPA, such as reading and reviewing scientific articles and reports on pesticide experiments, especially those concerned with environmental impacts. Of greater importance, however, is a multi-agency pesticide monitoring program in which EPA plays a central role. While several government agencies conducted certain monitoring studies prior to 1972, the FEPCA legislation mandated the Administrator of EPA to formulate a national monitoring plan: 15/

> Section 20(b) NATIONAL MONITORING PLAN: The Administrator shall formulate and periodically revise, in cooperation with other Federal, State, or local agencies, a national plan for monitoring pesticides.
>
> Section 20(c) MONITORING: The Administrator shall undertake such monitoring activities, including but not limited to monitoring in air, soil, water, man, plants, and animals,

> as may be necessary for the implementation of this Act and of the national pesticide monitoring plan. Such activities shall be carried out in cooperation with other Federal, State and local agencies.

EPA is now developing a comprehensive plan for monitoring pesticide residues in both human and animal tissue, as well as in the soil, water and air. While EPA will coordinate the plan and act as a central clearinghouse for the information gathered, the plan will involve several other government agencies on a cooperative basis, such as the Department of Agriculture (soils and crops; meat and poultry); the Department of Health, Education and Welfare (residues in food and feed; dietary intake; surveillance of crops and commodities) and the Department of Interior (water and wildlife). 16/

With the national pesticide monitoring plan well underway, EPA's own monitoring activities are increasingly involved with the daily mechanics of the regulatory process. In the past, these monitoring activities have been oriented toward the collection and dissemination of data in a widely useful published form, but the regulatory process is generating pressures for special-purpose data serving immediate internal needs of the Agency, at the cost of de-emphasizing publication. Since EPA's budget and resources are limited, it may be forced to trade-off between more timely information which is prepared only in "rough" form for extremely important internal uses versus more delayed information which is published in a more finished format. This is happening precisely at a time when the Freedom of Information Act is exposing all monitoring functions to a rising crossfire of outside demands for data. To cope with such conflicting demands, much tighter coordination of all internal functions may be required.

In response to such pressures, an internal reorganization and coordination process is now underway within EPA (see below). As a part of this process, EPA's Office of Pesticide Programs is designing and implementing a Hazard Evaluation System (HES) Program to complement other monitoring efforts. This program (discussed at greater length in Chapter 8) is concerned with the collection, verification and analysis of data, as well as with alerting and triggering mechanisms to be activated when the data indicate that special or previously unforeseen hazards are developing.

Adversary Proceedings Conducted by EPA

Since enactment of the 1972 FEPCA legislation, EPA has initiated cancellation actions against a number of pesticides. In several important cases, including DDT, aldrin/dieldrin and chlordane/heptachlor, an important issue -- or even the central issue -- was the question of whether residues of the pesticide or their metabolites are carcinogenic. The case of chlordane/heptachlor is discussed in more detail in Chapter 7.

As indicated previously, notices of cancellation and suspension are issued by the Administrator of EPA. The Administrator receives information and suggestions for initiating such actions from both within and outside EPA. In 1970, shortly after EPA was formed, the Environmental Defense Fund (EDF) petitioned the Administrator to cancel aldrin/dieldrin, and EDF has been a major outside influence in initiating action against several other pesticides, including DDT. Within EPA, the Office of Pesticide Programs (OPP) has the day-to-day responsibility for evaluating registration data, monitoring results and advising the Administrator if a hearing concerning cancellation of a pesticide's registration appears warranted. After a formal Notice to Cancel has been published in the Federal Register, affected parties have 30 days in which they may, as a matter of right, request a formal hearing. When a hearing is requested, preparation and presentation of the case is handled by the legal staff members in the Office of General Counsel (OGC) who act as proponent of the Agency's position and treat OPP as its client. 18/

In some instances, following issuance of a cancellation notice, no request for a hearing was received and cancellation then became "final and effective." This occurred, for instance, with some of the mercurial and arsenical pesticides. In the case of widely used pesticides such as DDT or aldrin/dieldrin, however, a cancellation notice will almost inevitably result in a petition for a formal hearing, and the elapsed time from issuance of the cancellation notice to the Administrator's final order may run many months, frequently years. Unless a suspension notice is issued, manufacture and use of the pesticide may continue at least until the Administrator issues a final decision, and beyond that time if the Administrator's decision is appealed in the courts.

A difficult problem is faced by an agency which must regulate low-probability risks whose lifetime incidence may vary between, say 10^{-4} and 10^{-10} per person 19/ and where direct cause and effect are not and can not be known with certainty. It should be noted that EPA now uses different criteria for the various decisions which it must make, such as initiating an action or issuing a final administrative order. In general, the courts have sanctioned this approach. In the early stages, for example, if the Administrator has reasonable suspicion for questioning whether a pesticide is carcinogenic, the courts have held that under the law he has a responsibility to issue a Notice of Intent to Cancel the registration, thereby triggering the creation of a public forum for the issue. Specifically, the courts have held:

> The legislative history supports the conclusion that Congress intended any substantial question of safety to trigger the issuance of cancellation notices 20/
>
> Public hearings bring the public into the decision-making process and create a record that facilitates judicial review. If hearings are held only after the Secretary is convinced beyond a doubt that cancellation is necessary, then they will be held too seldom and too late in the process to serve either of these functions effectively. 21/
>
> . . . . if the Administrator has a substantial doubt as to safety, it is his duty . . . to issue the cancellation order. (emphasis added) 22/

This means that in the face of conflicting scientific evidence about possible carcinogenicity, the Administrator has a responsibility to initiate action to cancel the registration of the pesticide in question. Neither definitive evidence nor a weighing of risks versus benefits is required at this point.

A decision to issue a Notice of Intent to Suspend registration must be based on suspicion plus reason to believe that an immediate hazard will result from continued use of the pesticide while the cancellation proceeding is in progress. The Administrator need not weigh risks versus benefits when deciding whether to issue a Notice of Intent to Suspend. However, a final decision to suspend can stand only if there is no evidence to substantiate that the original suspicion was unfounded, with the burden of proof placed on the registrant. A weighing of risks versus benefits must underlie any decision to suspend.

A final decision to cancel registration permanently results from a consideration of the most solid evidence of all, since the cancellation proceeding allows evidence to be developed in more detail. Burden of proof that the pesticide is safe rests with the registrant at all times, but the Administrator is obligated to weigh benefits against risk when making a final decision. This decision process will be analyzed in Chapter 8.

As a result of the record established during prior hearings and court appeals, we now have extensively documented public records of how administrative law judges and courts deal with issues raised by the possible carcinogenicity of pesticide residues. A less documented link in the total regulatory process, however, is the series of events which must necessarily precede the formal action that initiates an adversary process (i.e., issuance by the Administrator of a Notice of Intent to Cancel or Suspend the pesticide's registration). This process, which is still evolving within EPA, is also less open to public inspection than either administrative law proceedings or court records. Therefore, this case study has devoted particular attention to the following questions:

* What groups within EPA receive information concerning possible hazardous effect of pesticides?

* Who within EPA is responsible for analyzing information on hazards and initiating action to recommend cancellation or suspension of a pesticide where the information indicates that such action may be desirable?

* How much other information do those responsible EPA units receive? What are their other duties and responsibilities? Is it possible or likely that a flood of information to be processed, plus other organizational duties and responsibilities will prevent meaningful attention to pesticides that constitute potential problems?

- From a public policy viewpoint, to what extent should outside organizations (such as EDF) be relied upon to act as key catalysts in initiating action on behalf of the public interest? Should such agencies receive some kind of public funding, such as attorneys' fees, for actions which are ultimately successful?

- Can Congressional and political pressures be expected to influence EPA toward excessive or insufficient caution? Should EPA be given more or less independence? Are there organizational modifications that would promote a better average outcome?

Notes to Chapter 6

1. U.S.C. 1964 Title 7, Sect. 135 *et seq*. April 26, 1910, c. 191, 36 Stat. 331.

2. U.S.C. 1964 Title 21, Sects. 301-392, June 25, 1938, c. 675, 52 Stat. 1040.

3. U.S.C. 1964 Title 7, Sect. 135 *et*. *seq*. June 25, 1947, c. 125, 61 Stat. 163.

4. U.S.C. 1964 Title 7, Sects. 135-135b, 135f, 135g May 12, 1964, 78 Stat. 190.

5. 83rd Congress, Public Law 518, c. 559, 511, July 22, 1954.

6. 85th Congress, Public Law 929, 72 Stat., 1874, Sept. 6, 1958.

7. A good survey of this legislation from the legal point of view is found in Phillip L. Spector, "Regulation of Pesticides by the Environmental Protection Agency" *Ecology Law Quarterly* (1976), pp. 233-8.

8. Spector, "Regulation of Pesticides. . ." p. 233 fn. 2.

9. 92nd Congress, Public Law 516. See 7 U.S.C. Sect. 135 *et seq*. (Supp. III, 1973).

10. Spector, "Regulation of Pesticides. . ." p. 235 fn. 13 comments:

> This statutory standard is so vague as to amount to essentially no standard at all. At one time it might have been considered an unconstitutional delegation of legislative power, although it would probably be constitutional today. . . As one response to the problem of broad delegation, courts have required agencies to limit their own discretion by adopting more precise rules. . . EPA recently promulgated regulations that give somewhat more content to FEPCA's 'unreasonable adverse effects' test.

11. 94th Congress, Public Law 140, 89 Stat. 751, 7 U.S.C.S. Sects. 136-136b, 136p, 136s, 136w, 136y, November 28, 1975.

12. 94th Congress, Public Law 140, 89 Stat. 751, 7 U.S.C.S. Sects. 136-136b, 136b, 136p, 136s, 136w, 136y, November 28, 1975.

13. 94th Congress, Public Law 140, 89 Stat. 753.

14. Spector, "Regulation of Pesticides. . ." p. 236.

15. 92nd Congress, Public Law 516, 86 Stat. 973.

16. A detailed listing of Federal pesticide monitoring activities and sampling locations is presented in: Federal Working Group on Pest Management, Monitoring Panel Catalog of Federal Pesticide Monitoring Activities in Effect July 1973 (March 1975). See also:

    Spencer, Donald A. The National Pesticide Monitoring Program, an Overview of the First Ten Years of the Program's Operation (Washington, D.C.,: National Agricultural Chemicals Assn., 1974). This work includes a foreward by G. Bruce Wiersma, Branch Chief, Ecological Monitoring Branch, EPA.

    U.S. Environmental Protection Agency, Office of Pesticide Programs, "The National Pesticide Monitoring Plan -- Draft" September 11, 1975. This was prepared in response to the 1972 FEPCA legislative mandate and was seen only in draft form.

    U.S. Environmental Protection Agency, Office of Pesticide Programs, Ecological Monitoring Branch, Pesticide Monitoring, a Quarterly Report. This serial began with a combined issue (No. 1-2) for July/December 1975.

17. Under the proposed reorganization there will be an entire Hazard Evaluation Division to implement the HES Program. EPA has commissioned several outside studies on related projects, some of which were completed in time for our consideration. The most directly relevant report in this group is:

    U.S. Environmental Protection Agency, Office of Pesticide Programs, A Study to Develop Alternative Conceptual Approaches for a Pesticide Hazard Evaluation System (Cambridge, Mass.: Arthur D. Little, Inc., April 1976).

    Other studies are:

    U.S. Environmental Protection Agency, Office of Pesticide Programs, A Benefit-Cost System for Chemical Pesticides (Washingington, D.C.: Environmental Protection Agency, June 1975).

U.S. Environmental Protection Agency, Office of Pesticide Programs, Alternative Futures for Environmental Policy Planning: 1975-2000 (Washington, D.C.: Government Printing Office, October 1975).

18. Spector, "Regulation of Pesticides. . ." pp. 238-9. We confirmed this point in our interviews with EPA officials.

19. The meaning of these incidence levels can be illustrated as follows. "If our experiments are conducted in animals for their whole lifetimes (as they often are) and if we assume that results on animals are directly convertible to man (which is reasonable in the absence of data to the contrary), then the dose we set for a virtual safety level of 1 in 10^8 should give us a maximum of 2 additional cancers in a lifetime of individuals in a population of a size roughly that of the present United States." (Cited from Nathan Mantel and Marvin A. Schneiderman, "Estimating Safe Levels, a Hazardous Undertaking" Cancer Research (June 1975 p. 1380.) 1 in 10^8 is an incidence of probability of 10^{-8} per person. At a level of 10^{-4}, 20,000 additional cancers would result in a U.S.-size population while at a level of 10^{-10}, there would be a 2% lifetime risk for a single cancer in the entire population of the same size.

20. Environmental Defense Fund, Inc., v. Ruckelshaus, 439 F. 2d 584, 593-4 (1971).

21. Environmental Defense Fund, Inc., v. Ruckelshaus, 439 F. 2d 584, 595 (1971).

22. Dow Chemical Company v. Ruckelshaus, 477 F. 2d 1317 (1973).

7. Issues Raised in the Chlordane/Heptachlor Suspension Case

Chlordane has been manufactured and sold commercially since 1947, and heptachlor has been in use since about 1950. Under the 1947 Federal Insecticide, Fungicide and Rodenticide Act, which was in effect when these two pesticides were introduced, the Department of Agriculture did not have authority to deny or restrict the registration of any pesticide. For this reason chlordane and heptachlor were in use for many years before their effect on the environment was called into question.

The Widespread Use of Chlordane and Heptachlor

Technically, chlordane and heptachlor are both rather complicated insecticidal mixtures of chlorinated hydrocarbons. They persist in the soil for up to three years, and have been found to be effective against a number of pests capable of causing extensive damage to agricultural crops, damage to homes (termites), or irritation to humans (fire ants).

Usage of chlordane and heptachlor grew steadily from their introduction until the end of 1975, when their registration was partially suspended by the Administrator of EPA. 1/ By 1975, chlordane had become one of the leading insecticides in the United States, and accounted for almost six percent of total insecticide use. The record of the suspension hearing and the Administrative Law Judge's opinion contain a lengthy and detailed description of the specific pests, crops, and locales for which chlordane and heptachlor are effective. 2/ Table 2 indicates the number of pounds used annually, along with an approximate breakdown of the major types of usage. The principal agricultural use of these two insecticides is on corn; together they are used on about 3.5 percent of the total corn acreage in the United States. Prior to their suspension, over 23 million pounds of these two chemicals were being discharged into the environment each year.

In home and garden usage chlordane is more important than the data in Table 2 might indicate. In 1972, chlordane accounted for almost 23 percent of all insecticides used in homes and gardens. It also represented 30 percent of all industrial/commercial insecticides used at such places as factories, plants and airports.

Registration of the closely related pesticides aldrin and dieldrin was suspended in 1974, 3/ and the suspension affirmed by the Circuit Court of Appeals on April 4, 1975. The suspension of aldrin and dieldrin no doubt

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increased the use of chlordane and heptachlor in those applications where they were considered acceptable substitutes.

TABLE 2

Uses of Chlordane and Heptachlor, 1973 - 1974
(millions of pounds)

Use	Chlordane 1973	Chlordane 1974	Heptachlor 1973	Heptachlor 1974
Corn	1.94	4.32	1.13	1.19
Potatoes	0.98	1.11	--	--
Other vegetables	0.06	0.07	--	--
Home lawn and garden	5.77	6.33	--	--
Turf	1.14	1.25	--	--
Seed dressing	--	--	0.19	0.27
Strawberries	0.15	0.17	--	--
Tomatoes	0.30	0.33	--	--
Ornamentals	0.23	0.25	--	--
Percent classified otherwise	7.41	7.34	0.61	0.55
Fire ants, misc.	--	--	0.03	0.04
Total	17.98	21.18	1.97	2.05

Source: Recommended decision of the Administrative Law Judge in the hearing to suspend the registration of chlordane and heptachlor, December 12, 1975, EPA, FIFRA Doc. 384, pp. 20 & 22.

The Residue Problem

Under the mandate of the 1972 FEPCA legislation, as indicated in Chapter 6, EPA has been formulating a National Pesticide Monitoring Plan to coordinate existing monitoring programs of other agencies with those activities undertaken directly by EPA.

> The National Pesticide Monitoring Plan [NPMP] calls for development of a capability to integrate Regional

> and State networks with Federal Networks. . . These systems are expected eventually to enter data into the National Environmental Pesticide Data System (NEPDS). . . Current NPMP networks [were] originally designed and activated in response to the President's Science Advisory Committee Report in 1963. They are coordinated through the Monitoring Panel, FWGPM [Federal Working Group on Pest Management].
>
> Thus, while Section 20 (b) and (c) of the amended FIFRA has given the first legislative mandate to develop and operate a monitoring plan and system, such a system has, in fact, been operational for several years. The existing NPMP networks, with possible modifications, will be considered integral parts of the Plan. Their utilization represents the most efficient and effective alternative available in devising the Plan.
>
> Both EPA and the Monitoring Panel are reviewing existing networks and modifying [them] when necessary. 4/
>
> The Monitoring Panel, FWGPM, operates under executive order through the Council on Environmental Quality, and supports the existing NPMP Networks in an advisory capacity. With the enactment of FIFRA, as amended, broadened operational coordination responsibilities are delegated to the Administrator of the Environmental Protection Agency. The Plan, therefore, calls for creation of an interagency Pesticide Monitoring Coordination Council (PMCC) to coordinate operational aspects of all pesticide monitoring activities conducted in fulfillment of Section 20 (b) and (c). PMCC would be comprised of those individuals directly in charge of the monitoring program of the involved agencies. Council members would necessarily be authorized to represent their agency in matters of coordination and be provided adequate resources from their respective agencies to do so. As mandated, EPA would take the lead in this cooperative effort. Understandably, such cooperation could result in the need for formal, interagency agreements. 5/

Findings from the various existing monitoring programs and special monitoring studies indicate that chlordane, heptachlor, and their derivatives and metabolites have an ubiquitous presence in humans throughout the United States. Highlights of these results and analyses, summarized here, indicate the nature and extent of the problem.

Human Adipose Tissue. The National Human Monitoring Program found positive amounts of oxychlordane in at least 92 percent of the adipose tissues analyzed between 1971 (the first year the survey had the capability to detect oxychlordane residue in human adipose tissue) and 1974. 6/ Results of this survey are summarized in Table 3. The concentration of oxychlordane in human adipose tissue has been found to increase with age, an additional finding not reflected in Table 3.

TABLE 3.

Oxychlordane Residue Found in Human Adipose Tissue, 1971 - 1974

Year	Percent Positive	Percent Trace
1971	93.27	0.95
1972	92.29	2.71
1973	98.35	1.01
1974	98.55	1.22

Source: Recommended decision of the Administrative Law Judge in the hearing to suspend the registration of chlordane and heptachlor, December 12, 1975, EPA, FIFRA Doc. 384, p. 10

During the years 1970 - 1974, heptachlor epoxide was found in over 90 percent of the human adipose tissues analyzed in the National Human Monitoring Program. Results of this program are summarized in Table 4. As with oxychlordane, the concentration of heptachlor epoxide increased with the age of the subject in every year of the survey with the exception of the data collected in 1974.

TABLE 4

Heptachlor Epoxide Residue Found in Human Adipose Tissue, 1970 - 1974

Year	Percent Positive	Percent Trace	Mean ppm	Maximum ppm
1970	94.76	3.61	0.17	10.62
1971	96.23	3.47	0.12	1.53
1972	90.26	2.86	0.12	1.21
1973	97.71	1.92	0.12	0.84
1974	96.33	3.45	0.10	0.77

Source: Recommended decision of the Administrative Law Judge in the hearing to suspend the registration of chlordane and heptachlor, December 12, 1975, EPA, FIFRA Doc. 384, pp. 9-10.

Human milk. An analysis of 57 human breast milk samples taken in 1974 found quantifiable levels of heptachlor epoxide in 35.1 percent of all samples. Quantifiable levels of oxychlordane were found in 45.6 percent of all samples. One hundred percent of the milk analyzed contained at least trace amounts of either heptachlor epoxide or oxychlordane (a trace represents a positive finding of residue which cannot be quantified). 7/

Human fetuses. Heptachlor epoxide was also found to cross the placental barrier and enter the human fetus. A study of residues of various chlorinated hydrocarbons in different tissues from stillborn infants found measurable concentrations of heptachlor epoxide in adipose tissue, spinal cord, adrenals, lungs, heart, liver, kidney, and spleen. Heptachlor epoxide was identified in the cord blood of 27 out of 30 normal newborn infants. 8/

Urban soil. The Urban Soils Monitoring Program detected residues of chlordane in the soils of all 37 cities sampled between fiscal years 1970 and 1974; heptachlor epoxide was detected in 28 cities and heptachlor in 13 cities. In many cities, chlordane was detected in approximately 20 to 40 percent of all samples taken, and in several cities heptachlor epoxide residues were present in 10 to 20 percent of the soil samples. The data from the Urban Soils Monitoring Program thus indicate that residues of chlordane, heptachlor and heptachlor epoxide are widespread in urban areas, reflecting the common use of chlordane in and around human dwellings for control of lawn and garden pests. 9/

Water and shellfish. The widespread usage of chlordane and heptachlor for gardens and turf creates a certain amount of runoff which introduces residues into streams, rivers, lakes, and estuaries. A study of the Chester River in Maryland established that the alpha and gamma isomers of chlordane were present in its shellfish, finfish, crabs and sediment. The average concentrations found in this study were relatively small. However, laboratory experiments have demonstrated that shellfish readily accumulate chlordane to high levels from very low concentrations in the water. For example, when exposed to a level of about 1 part per trillion in the water, oysters concentrated chlordane 160,000 times; under similar circumstances, soft-shelled crabs concentrated chlordane 35,000 times. 10/

Everyday foods. Finally, the National Pesticide Monitoring Program on Foods has found that residues of heptachlor and heptachlor epoxide appear most frequently in foods of animal origin; that is, in dairy products, meat, fish and poultry. Based on the total diet monitoring program, the percent incidence of heptachlor-heptachlor epoxide in all food classes has remained relatively unchanged for the 1965 - 1974 period, but the calculated daily intake in mg/kg body weight has gradually but steadily declined during the same period. The food residue levels of heptachlor, heptachlor epoxide and chlordane are low. Heptachlor-heptachlor epoxide residues were present in 0.8 to 2.0 percent of the average daily intake for 1970 - 1974. Chlordane residues comprise less than 1/100 of 1 percent of the ADI. Chlordane findings in the surveillance program, although still low, have increased recently; a change perhaps due to improved analytical techniques, but more likely to the recent increase in the agricultural use of chlordane. 11/

Evaluating the Risk of Cancer

The record of the chlordane/heptachlor suspension hearing provides a good illustration of the difficulties in evaluating the risk of cancer and the hazard to society posed by such risks. One of the more significant problems is that with a disease like cancer, any thought of carrying out controlled experiments on humans is abhorrent and it is not feasible to wait for or contemplate "happenstance" epidemiological studies (e.g., the accidental overexposure to some group, such as workers in a plant manufacturing or fabricating the chemical). Even if such accidental overexposure were to occur, epidemiological studies would require decades because of (1) the long gestation period of cancer (even then the results might be inconclusive because of the small number of workers involved); (2) the lack of any precise knowledge about prior or subsequent exposure of the workers to other carcinogens; (3) the known wide susceptibility of humans to cancer; and (4) our lack of knowledge about what causes this susceptibility. In the case of an ubiquitous pesticide like chlordane or heptachlor, control groups are almost impossible to obtain. It might be possible to undertake an epidemiological study among people who live in areas where the use of chlordane and heptachlor are most concentrated. 12/ However, if we waited until a validated epidemiological study indicated that the pesticide was definitely carcinogenic, we would be faced with a serious situation indeed.

Because valid epidemiological studies are not likely, controlled experiments with animals are relied upon for determining the carcinogenicity of a pesticide. Though such animal experiments are used for a wide range of purposes, extrapolation of the findings of animal studies to man is not straightforward because different species of animals react differently to biologically active substances. 13/ In this vein, it is known that humans are more sensitive to certain substances than are the generally used laboratory animals. The reverse possibility also exists, creating severe difficulties in extrapolating "from an inbred mouse strain to a genetically heterogenous population such as man." 14/ Among the problems encountered are: variations in dose-response curves; uncertainty about the proper basis of dose transfer for variations in body size, e.g., relative weights or relative surface areas; variations of retention times for materials, based on metabolic rates and ratios of blood volume to circulation time; variations in plasma protein and tissue binding; variations in the rate of hepatic metabolism of foreign compounds; and variations in the generation and repair times of cells, affecting realignment or mutagenic change and the relative stability or variability in the life environments of the species compared. 15/

Still another cause of uncertainty is that even when substances are fed to animals under controlled circumstances, it is often impossible to state conclusively that the substance itself is either cancerous or non-cancerous. The chemical may cause lesions of specific organs -- e.g., chlordane and heptachlor affect the liver -- and these can cause tumors which in turn may be benign or malignant. Malignancy is confirmed if metastases are found, but the absence of metastases does not confirm that a tumor is benign. Moreover, benign tumors sometimes turn into malignancies; hence benign tumors themselves pose some risk of cancer, although the risk is not as high as it would be if the test animals exhibited malignancies. 16/

Finally, even if a controlled experiment shows that concentrated doses of a substance do induce lesions and cancer in animals, there is major uncertainty as to whether the relationship between dosage and observed consequences is linear. For example, will one-hundredth of the dosage have one-hundredth the probability of producing a lesion, or is there some threshold below which minute quantities are inconsequential, and above which risk increases at an increasing rate? Evidence on this issue is almost totally lacking. We do know, however, for some carcinogenic agents, especially ionizing radiation, that the higher the dosage one is exposed to, and the longer one is exposed to it, the higher the probability of cancer. Lack of specific knowledge about possible threshold effects merely increases the uncertainty about a substance or agent which is possibly carcinogenic. 17/

Based on the varying evidence on carcinogenicity offered during the suspension hearing of chlordane and heptachlor, Chief Administrative Law Judge Herbert L. Perlman took the following position: 18/

> . . .we conclude that heptachlor and its metabolites appear to be a carcinogen in the mouse. . .and may be a carcinogen in the CFN rat. . .and that chlordane appears to be a carcinogen in the mouse. . . [We] feel very strongly that these matters should be reviewed by others more qualified with respect to pathology than we for a more definitive appraisal. In other words we are hesitantly unwilling at this time to find that heptachlor and chlordane are conclusively carcinogens in laboratory animals.

The judge, however, added the following comment: 19/

> The Administrator could perhaps do so on the basis of this record. . . [which] contains no valid epidemiological proof that the pesticides at issue are safe with respect to the question of cancer and otherwise does not take into consideration other avenues of exposure to the chemicals such as inhalation and dermal contact, nor does it account for the wide variability in human susceptibility as compared to laboratory animals and different degrees of exposure, and considers exposure only to a simple carcinogen. . . In reality, the attempt to establish a safe level of a carcinogen for man is in its infancy.

Judge Perlman, in keeping with these reservations, cautioned: 20/

> We do not wish to leave the impression that the safety of heptachlor and chlordane is not still a matter of grave concern. In other words, they are not "home free" by any means with respect to whether they are carcinogens in laboratory animals and a potential carcinogenic risk to man. We merely state that at this time we do not so conclude

> and, by reason thereof, we cannot find an "imminent hazard" with respect thereto.

On this basis the Administrative Law Judge recommended that the notice of intention to suspend chlordane and heptachlor be dismissed and that final determination of the issues raised by chlordane and heptachlor rest solely on the outcome of the cancellation proceeding.

The Administrator of EPA did not concur with all of the Administrative Law Judge's conclusions. His stated reasons for arriving at different conclusions were as follows: 21/

> In sum, therefore, the ALJ's precise holding that there was no "imminent hazard," and thus no basis for suspension under section 6(c) of the FIFRA (1) was made without balancing the risks of continued use of chlordane and heptachlor against the benefits of that use, and (2) was grounded solely on the holding he was "hesitantly unwilling" to find that chlordane and heptachlor are "conclusively" carcinogens in laboratory animals even though they both "appear to be" such carcinogens and the question of their safety on this score is "a matter of grave concern."
>
> Both of these holdings contain misapplication of the pertinent statutory provisions and controlling judicial decisions.
>
> Section 6(c) (1) of the FIFRA provides that the Administrator suspend the registration of pesticides where "that action is necessary to prevent an imminent hazard during the time required for cancellation proceedings. . .
>
> The term "imminent hazard" is defined in Section 2(1), in pertinent part, as "a situation which exists when the continued use of a pesticide during the time required for cancellation proceeding would be likely to result in unreasonable adverse effects on the environment. . .
>
> The phrase "unreasonable adverse effects on the environment", in turn, is defined in section 2(bb) to mean, "any unreasonable risk to man or the environment, taking into account the economic, social and environmental costs and benefits of any pesticide."
>
> Thus, in combination, section 6(c)(1), 2(e), and 2(bb) provide that suspension depends upon a finding that continued use of a pesticide during the time required for a cancellation proceeding would be likely to result in any unreasonable risk to man or the environment, taking into account the economic, social and environmental costs and benefits of the use of the pesticide.

As the courts have held (and, indeed, as counsel for the registrant have urged in this proceeding), the question of the "reasonableness" of the risk presented depends upon an assessment of the nature and magnitude of risk of harm to man or the environment as compared to the nature and magnitude of economic, social, and environmental benefits which are derived from the use of the pesticide during the time required for a cancellation proceeding. 22/

Thus, the FIFRA and the cases, in my opinion, make two points clear with regard to a suspension proceeding. First, it is not necessary to find "conclusively" that actual harm to man will occur if the use of the pesticide in question is continued; rather the finding required is that continued use during the cancellation proceeding is "likely" to result in any "unreasonable risk" to man or the environment. As the court of appeals has held:

> [T]he term "imminent hazard" is not limited to a concept of crisis: It is enough if there is substantial likelihood that serious harm will be experienced during the year or two required in realistic projection of the (cancellation) process. 23/

Second, the propriety of suspension turns upon an analysis in which the risks are balanced against the benefits, rather than from an analysis of risks or benefits alone.

It should also be noted that the mere fact that the evidence on either of these issues (risks or benefits) is not complete, or that more evidence may be expected to be developed in the cancellation proceeding, is not a reason to deny suspension. Suspension is an interim remedy, to be determined on a record assembled on an expedited basis, as was the case here. Congress must have expected that the record of a suspension proceeding would not contain all the evidence on crucial questions that would be expected and presented in a cancellation proceeding. As the court of appeals has held:

> [T]he function of the suspension decision is to make a preliminary assessment of evidence and probabilities, not an ultimate resolution of difficult issues. 24/

For the foregoing reasons, I find that the ground given by the Administrative Law Judge in determining not to recommend suspension of the registration of heptachlor and chlordane is deficient as a matter of law. He failed to weigh adequately the risks in relation to the benefits as required by the statute and by Agency policy. Moreover, he held that the fact that the carcinogenicity of heptachlor and chlordane had not been

> "conclusively" established with respect to laboratory animals was determinative of the potential risk of cancer to man, even though the statute talks in terms of the likelihood of an unreasonable risk. Indeed, I believe that this much less stringent statutory standard was met by Judge Perlman's findings that heptachlor and chlordane "appear to be" carcinogenic in laboratory animals and are pesticides whose safety is a matter of "grave concern." In the same vein, the courts have also insisted that the burden of proof of the safety of a pesticide lies at all times with the registrant. 25/ Thus insofar as the showing of risk of harm from heptachlor and chlordane is not yet conclusive, it should be emphasized that it is not the Agency's burden to establish the risk of harm, but rather the registrant's burden to disprove it once its safety has been called into question by a sufficient showing of probable risk.

Thus, as shown by the record of this suspension proceeding, the courts and EPA have adopted a position which lies rather close to the Delaney Clause used by the FDA in evaluating food additives. That is, the likelihood of a pesticide causing cancer in animals will be interpreted to imply that it is also likely to cause cancer in man, and this in general constitutes sufficient grounds for suspending registration for any use likely to result in residue in the human food supply.

The key difference between this position and the Delaney Clause is that benefits have been weighed against risks, whereas the Delaney Clause leaves no discretion whatever for consideration of benefits. Certain exceptions were made on the grounds that benefits outweighed risks. The uses most essential for continued production and whose denial would have concentrated adverse economic impacts in particular areas -- as was found to be the case with the Hawaiian pineapple crop and a few other minor uses of chlordane and heptachlor -- were exempted from the suspension order. Likewise, to prevent immediate, major economic loss to producers, distributors and users, it was authorized that existing stores of the pesticides could be used during the 1976 crop year.

Some of the theoretical issues raised by this case study will be covered in the next section.

Notes to Chapter 7

1. U.S. Environmental Protection Agency, Suspension Proceedings Before the Administrator, Decision of the Administrator on the Suspension of Heptachlor-Chlordane, in re Velsical Chemical Corporation et al., registrants, FIFRA Docket No. 384, Expedited Hearing on Heptachlor-Chlordane; dated December 24, 1975, 77pp.

2. U.S. Environmental Protection Agency, Before the Administrator, Recommended Decision, by Herbert A. Perlman, Chief Administration Law Judge, in re Velsical Chemical Corporation et al., Registrants, FIFRA Docket No. 384, Expedited Hearing on Heptachlor-Chlordane; dated December 12, 1975, 122pp.

3. U.S. Environmental Protection Agency, "Opinion and Order of the Administrator, Environmental Protection Agency, in the Suspension of aldrin-dieldrin," Federal Register, v. 39, no. 203, Part 1, October 18, 1974, 37265-37272.

4. U.S. Environmental Protection Agency, Office of Pesticide Programs, The National Pesticide Monitoring Plan, Draft, Sept. 11, 1975, p. 10.

5. U.S. Environmental Protection Agency, Office of Pesticide Programs, The National Pesticide Monitoring Plan, pp. 12-13.

6. National Human Monitoring Program, cited in U.S. Environmental Protection Agency, Before the Commissioner, Recommended Decision, p. 10. This program is incorporated in Environmental Protection Agency, Office of Pesticide Programs, "National Pesticide Monitoring Plan" pp. 42-43.

7. U.S. Environmental Protection Agency, Before the Commissioner, Recommended Decision, p. 11.

8. U.S. Environmental Protection Agency, Before the Commissioner, Recommended Decision, p. 12.

9. U.S. Environmental Protection Agency, Before the Commissioner, Recommended Decision, pp. 12-13; see also U.S. Environmental Protection Agency, Office of Pesticide Programs, The National Pesticide Monitoring Program, p. 17. The Urban Soils Monitoring Program is incorporated in the EPA plan (see note 4 above) as a component of the National Soils Monitoring Network which also includes two other components cropland and noncropland.

10. Cited in U.S. Environmental Protection Agency, Before the Commissioner, Recommended Decision, pp. 14-17.

11. U.S. Environmental Protection Agency, Before the Commissioner, Recommended Decision, pp. 18-19.

12. The highest use of chlordane occurred in Missouri bottomland, where farmers applied the pesticide each year as "insurance" against the corn cutworm. According to the record of the suspension hearing, thirty percent of all corn grown in Missouri, and most of the corn grown on bottomland, was treated with chlordane. Locally produced meat, milk, chicken and eggs might be expected to have higher concentrations of chlordane. To the extent that those who live on farms and in small rural communities consume high proportions of locally produced foods, they would have greater exposure to chlordane.

13. Of the several technical articles analyzing carcinogenic risk which have been introduced into evidence at the suspension hearing, the one which addresses this issue most directly -- and is also by far the most readable for policy makers without losing any of its analytic incisiveness -- is "From Mouse to Man -- or How to get from the Laboratory to Park Avenue and 59th Street," by Marvin A. Schneiderman, Nathan Mantel, and Charles C. Brown, Annals of the New York Academy of Science, (Jan. 31, 1975).

14. Schneiderman, "From Mouse to Man. . ." p. 245.

15. Schneiderman, "From Mouse to Man. . ." p. 245.

16. The transcript of the suspension hearings contains many examples of disagreements by expert witnesses over the nature and significance of histological and other pathological findings.

17. The fundamental article on the statistical analysis of carcinogenicity test results is "Safety Testing of Carcinogenic Agents," by Nathan Mantel and W. Ray Bryan, Journal of the National Cancer Institute (August 1961) pp. 455-470. The proceedings are reviewed fifteen years later in "Estimating Safe Levels or Hazardous Underestimating," by Nathan Mantel and Marvin A. Schneiderman, in Cancer Research (June 1975) pp. 1379-86. The same ground has been covered exhaustively by the Subcommittee on Estimation of Risks of Irreversible Delayed Toxicity of the Committee to Coordinate Toxicology and Related Programs of the U.S. Department of Health, Education and Welfare. The report of this subcommittee has been published as "Estimation of Risks of Irreversible Delayed Toxicity" by David G. Hoel and others in Journal of Toxicology and Environmental Health (1975) pp. 133-151. The four articles cited in this note and in note 13 above have been introduced into evidence at the suspension hearings by the U.S. Environmental Protection Agency.

18. U.S. Environmental Protection Agency, Before the Commissioner, Recommended Decision, p. 86. Emphasis in original.

19. U.S. Environmental Protection Agency, Before the Commissioner, Recommended Decision, p. 86. Emphasis in original.

20. U.S. Environmental Protection Agency, Before the Commissioner, Recommended Decision, p. 87. Emphasis in original.

21. The entire following passage is cited from U.S. Environmental Protection Agency, Suspension Proceedings Before the Commissioner. Decision of the Administrator on the Suspension of Heptachlor-Chlordane, pp. 9-12.

22. Environmental Defense Fund v. Environmental Protection Agency, 510 F. 2d 1292, 1302 (C.A.D.C. 1975); Environmental Defense Fund v. Environmental Protection Agency, 465 F. 2d 528, 538 (C.A.D.C. 1972). (footnote in original).

23. Environmental Defense Fund v. Environmental Protection Agency, supra, 510 F 2d at 1297, citing Environmental Defense Fund v. Environmental Protection Agency, supra, 465 F 2d at 540. (footnote in original).

24. Environmental Defense Fund v. Environmental Protection Agency, supra, 510 F 2d at 1297, citing Environmental Defense Fund v. Environmental Protection Agency, supra, 465 F 2d at 537. (footnote in original).

25. Environmental Defense Fund v. Environmental Protection Agency, supra, 510 F 2d at 1297; Dow Chemical Co. v. Ruckelshaus, 477 F 2d 1317, 1324 (C.A. 8 1973). (footnote in original).

8. Theoretical Issues Posed by Potentially Carcinogenic Pesticides

Products containing chlordane and heptachlor are among the thousands of pesticide products available through suppliers. The products are bought for agricultural, garden, and other insect control purposes, by both business firms and consumers. Farms and other pesticide-using businesses in turn sell agricultural products, or services such as termite-proofing for housing, to the ultimate consumer. As a result of this widespread distribution and use the chemical constituents of chlordane, heptachlor, oxychlordane and heptachlor epoxide now appear almost ubiquitously as a trace component in the environment, in our food, and in our body tissue. Continued exposure to traces of pesticide residues may carry low-grade but widespread carcinogenic risks.

One theoretical approach to decision-making under risk is based on the maximization of expected utility (by households) and expected profits (by businesses) in the hypothetical framework of a perfectly competitive market. In this idealized market the forces of supply and demand establish an equilibrium with a number of desirable properties. Since the attendant risks with which this study is concerned arise in the context of market transactions between several kinds of sellers and many different buyers, it is instructive to approach a theory of such risks in a market context. While the idealization inherent in the neoclassical concept of the market introduces a series of caveats into any such analysis, the theoretical framework is so deeply entrenched in the thinking of economists that we take it as our baseline, if for no other reason than to lay bare its limitations.

An alternative theoretical approach to decision-making under risk involves centralized decisions based on a systematic comparison of alternatives. Hazards to the public are considered in the context of economic, social and environmental costs and benefits. This approach is embodied in the 1972 Federal Environmental Pesticide Control Act, which amended the 1947 FIFRA legislation. This legislation requires that the Environmental Protection Agency employ risk-benefit analysis within the context of what we will refer to as a "sequential decision-making process."

The purpose of this chapter is to examine the applicability of these and other possible theoretical approaches to decision-making under risk. The chapter deals with the following principal topics, illustrated throughout with examples drawn from specific considerations raised by chlordane and heptachlor:

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* Market-based theories of decision-making
* The existing sequential decision process
* Risk-benefit analysis
* Dynamic considerations

Market-based Theories of Decision-making

As indicated above, the central theoretical approach of neoclassical economics to decision-making is based on maximization of utility and profits within an idealized market context. 1/ In a world of perfect competition, with no risk or uncertainty, consumers are assumed to maximize their individual utility functions, and business firms are assumed to maximize profits. Consumers and business firms both are taken to have complete information about all relevant aspects of their market transactions. Under these postulates, market prices provide necessary and sufficient information for consumers and producers to maximize their respective utility and profits. If all benefits and costs of market transactions accrue to the parties directly involved in the transaction -- that is, if the transactions do not have any external effects associated with them -- individual, decentralized decision-making not only enables individual consumers and business firms to maximize their respective objectives; it also leads to a socially efficient distribution of goods and services, given the initial distribution of assets. Efficiency is based on the criterion of "Pareto optimality," which, in brief, states that an efficient distribution of goods and services is achieved when there is no way of making one person better off without making another person worse off.

In a perfectly competitive model, market prices are assumed to reflect all social costs and benefits of production, and it is assumed that all social costs and benefits from a market transaction accrue exclusively to the buyer and seller. If third parties, who are in no way engaged in the production or consumption of an item, are adversely affected by the production and consumption of an item, other than through a change in market prices, external diseconomies are said to exist. It has long been recognized that the existence of external diseconomies can cause market failure; i.e., choices arrived at in a decentralized market will not be socially optimal. Market failure occurs because prices no longer reflect true social cost, and consumers and producers thus base their decisions on imperfect information. 2/

The existence of external diseconomies raises the issue of whether some means can be found to internalize social costs, so that individual decisions in the market can be restored as a desirable means by which individual and collective decisions are made.

The discussion of external diseconomies is pertinent to pesticides, because any carcinogenic microscopic residue can be classified as an external diseconomy. When pesticides are used on a farm, residues from the pesticide will almost surely persist on some of the farm products; the more persistent the pesticide, the more likely it is that residues will wind up in human consumption and, subsequently, in human tissue. Moreover, residues from almost all uses, including lawn and garden applications, are washed into streams or rivers, thereby contaminating the water supply of those downstream. When contaminated water enters bays or estuaries, some of these residues may become concentrated in shellfish, such as oysters. Those who drink the water or eat the shellfish will also ingest microscopic amounts of the carcinogen, which may cause cancer.

Note that our statement is that such a residue "may cause cancer." We are not dealing with an external diseconomy that arises in every instance with perfect certainty; rather, it is one that occurs with a low probability, but whose consequences are serious for anyone who does in fact develop cancer from exposure to carcinogenic residues. Thus pesticide residues not only raise issues traditionally associated with external diseconomies; they also raise issues that arise from considerations of risk and uncertainty. Of importance from a public policy viewpoint is the fact that almost all citizens are exposed to some amounts of the residue, and that this exposure may eventually cause cancer in a sufficient number of people to be deemed catastrophic.

The existence of risk and uncertainty can cause market failure even when there are no external diseconomies. For a neoclassical market to operate in the presence of uncertainties, perfectly competitive sub-markets would have to exist in all relevant insurance contracts affecting commodities traded. 3/ Gaps in the insurance market can cause the efficient allocation of resources to break down. This form of failure can present a serious problem for market-based solutions. 4/

Statistical uncertainty can be introduced into the perfectly competitive model in either of two ways. First, it may be assumed that the probability distributions of all uncertain variables are known, and that consumers and producers maximize expected values rather than fixed functions. In any particular instance, the actual value of an uncertain variable may deviate from its expected value, but this does not alter the fact that consumers and producers, making decentralized decisions guided only by their self-interest, will arrive at the best choices compatible with their uncertain conditions.

Second, under the assumptions of Bayesian statistics, consumers and producers are taken to have formed initial perceptions or judgments concerning the distribution functions of all uncertain variables. These *a priori* distributions need not correspond to the true distributions (which are unknown). If people use observed outcomes to correct their *a priori* perceptions and if underlying distributions do not change, then over time the *a priori* distributions will approach the true distributions. The results derived from a model incorporating Bayesian assumptions are often similar to those derived from a model that incorporates classical assumptions. Namely, decentralized decision-makers select those alternatives that are as good as any which could be selected under the circumstances, and are as good -- at the limit of a series of iterations -- as the ones that could result from known probability distributions.

One crucial difference between a world with known probability distributions and a Bayesian world, however, is that in a Bayesian world the value of information is substantially enhanced, to the point where it becomes an economic commodity that may have a price of its own. The mere pooling of information will have value and the production of certain types of information is likely to occur under conditions of high fixed and low marginal cost. Indivisibilities introduced by fixed costs will in turn tend to undermine decentralized market equilibrium. Another problem can arise if various agents in the economy have differing perceptions of the probability distributions floating around the world. Should this occur, individual actions may interact and affect each other in such a way as to leave everyone feeling worse off than they would feel under a collective solution.

Despite these theoretical considerations, in the eyes of most economists the introduction of risk and uncertainty does not, per se, demolish the applicability or intellectual appeal of the market model. The existence of uncertainty merely implies that outcomes will vary even under similar conditions, and that realized outcomes will not always equal the expected values of these outcomes. That is, for reasons unknown some people may wind up with less than both parties expected -- e.g., some people will unknowingly buy "lemons", or products that do not perform up to anyone's expectations, including the seller's. When this occurs, actual realized cost and benefits will typically differ at times by a large amount from expected costs and benefits.

These problems are not new, nor are they restricted to low-probability, high-consequence occurrences. In order to overcome the very real problems introduced by risk and uncertainty, and to facilitate the operation of markets, a number of legal safeguards and risk-spreading institutions have been created. In many instances these have restored faith in the applicability and desirability of the market model. We therefore review the potential applicability of such legal safeguards and risk-spreading institutions to the risk of cancer posed by pesticides like chlordane and heptachlor.

Propagation of accurate information. Over the years, Congress has enacted many laws requiring product labels to contain some minimum amount of accurate information. The original 1910 Pesticide Act, as well as the 1947 FIFRA legislation, were essentially of this type. Availability of such information, especially if it is prominently displayed, helps prevent fraud, deceit and misuse. Admittedly, such laws constrain the actions of producers, and in so doing appear to violate the freedom of adjustments required by the theory of a perfectly competitive market. However, this type of legislation does not displace the market as the central arena of fundamental decisions. In a world of uncertainty and imperfect information, the principal intent of such legislation is to help make market decisions more informed. An important underlying premise is that potential users, when provided with adequate information, will act at least as wisely in their own behalf as would anyone else who made decisions and choices for them. It should be noted, however, that it is not easy to decide which and how much information is useful and worthwhile to potential purchasers. Due to decision-making costs, the consumer often finds it more economical to grope for crude indicators of overall worth to him (e.g., brand name, regular gas, little cars get more miles per gallon than big cars) than to attempt a more technical comparison of the characteristics of different products. It is often difficult, therefore, for an expert to decide just what kind of information will be valuable to users and consumers.

The provision of more and better information has been adopted by Congress in many contexts. For example, this approach has been central to dealing with the health threat posed by cigarettes. The hazard involved in smoking is noted on every pack and has also been widely publicized in the news media. Individual preferences revealed to date -- i.e., continued high consumption of cigarettes -- indicate that many people either play down the risk of cancer or do not impute much utility to increasing the probability of living longer.

The same general approach of improving information and then permitting free choices within the context of the market mechanism might also be considered for pesticides. One possibility would be to label food (such as corn) according to the amount of potentially dangerous pesticide residues which it contains, and then permit market prices to adjust accordingly. The price level of contaminated food would presumably drop so as to reflect the discount which people put on the presence of such residues. If all corn were sold directly for human consumption this approach would at least be feasible. It might even be a practicable solution to the residue problem.

Most corn, however, is not directly consumed. If corn containing a pesticide residue were sold at a lower price, such corn might well be bought preferentially to feed cattle and poultry. All residue in corn would then wind up in meat and dairy products, as some of it does now. From a theoretical viewpoint, one could test all steers, cows, or chickens for residues of pesticides like chlordane or heptachlor, and provide appropriate labels on all products along the entire product chain. The cost of any such program, however, could well exceed the cost of eliminating the offending pesticides altogether. Consequently, the option of providing consumers with information that is accurate and sufficient for them to make more informed market choices does not appear to be practicable. Some other way must be found to deal with microscopic amounts of pesticide residues that are potentially carcinogenic, especially those residues which become so widespread in the environment that they can appear in food products that are totally unrelated to the crop originally treated with the pesticide; for example, shellfish, eggs and butter.

Compensation to those injured by uncertain events. In the course of producing or selling goods and services, events sometimes occur in which a person suffers ill consequences and economic losses resulting from circumstances that were not of his own making. Such events are sometimes freaks of nature, like violent storms that sink ships at sea; sometimes they are accidents, such as a train derailment; and sometimes they are caused by the actions of other people. When a person suffers adverse consequences that are not socially sanctioned and that can be attributed to someone else's intent or negligence, the law of torts frequently provides a partial remedy in the form of compensation for losses suffered. That is, the party adversely affected can sue the party at fault for damages, and defendants who are held responsible must pay the damages. To the extent that such laws apply, their effect is to make firms responsible for the consequences of their actions and for the effects of their products, thus giving the firms the motivation to forestall accidents and lawsuits, especially when potential damages exceed other gains. 5/

The law of torts is not the only way in which the social costs of uncertainty and occasional undesirable outcomes are internalized in the production process. In certain instances where risks must inevitably be incurred even under prudent management, strict or absolute liability -- i.e., liability regardless of fault -- has been imposed on firms in order to help protect and compensate those who suffer unintended ill consequences. Workmen's compensation laws, which provide reparations for anyone injured on the job, are of this type. If a workman is injured on the job, regardless of whether the accident results from uncontrollable circumstances, or from negligence by management -- or even negligence by the injured worker himself -- the law requires a certain amount of compensation for the person's economic losses. Most firms carry workmen's compensation insurance to cover their legal obligation, but a few larger firms self-insure. This "no-fault" approach to job-related accidents not only provides compensation for economic losses but, to the extent that a firm's rates for workmen's compensation insurance reflect its accident experience, the system also gives each firm an incentive to conduct an aggressive safety and accident prevention program.

Still another legal approach used to shift social costs back to producers and compensate consumers is the doctrine of implied warranty, which is often used to compensate people who have in some way been injured or suffered economic loss from defective products. In many states the legal doctrine of strict liability is now applied to cases involving product liability. Many firms purchase product liability insurance to cover this risk. 6/

In all of these cases -- negligence, absolute liability, implied warranty, or strict liability -- the law helps shift the social cost of risks and hazards from the individual consumer who suffers the injury back to the producer. The market mechanism, with its decentralized decision-making mode, functions within this legal framework. Regarding pesticides the question is: Would application or extension of any of these legal doctrines provide an adequate way of coping with risk of cancer from pesticide residues? The problem with applying any of these legal doctrines is that even when a person is known to have developed cancer, it is generally impossible at the current stage of knowledge, to determine whether the cancer was caused by any of the many carcinogens in the environment and if so, which carcinogen. Unless and until it becomes possible to establish such cause-and-effect relationships, none of these legal doctrines will lead manufacturers to take account of the social hazards and costs of producing, selling or using pesticides. Our ignorance of these relationships is, of course, also a serious handicap in devising other policy measures.

Direct levies on producers to reflect social costs. One policy approach suggested for some environmental problems is to impose taxes designed to internalize the social costs of undesirable environmental effects that arise from the production process. More specifically, in the case of manufacturing plants that discharge pollutants into the air or water, the efficacy of an effluent charge has been widely discussed by economists. This approach suggests still another possible way of internalizing the social costs that arise from the risks of cancer. Namely, instead of issuing regulations or restrictions governing various and sundry uses, the government could impose a "residue tax" on the pesticides in question, and then allow market forces to determine the extent to which the pesticide will be used.

The contrast between a residue tax and the present regulatory approach is interesting. Regulatory decisions, by their very nature, have a dichotomous (on-off) character. In other words, the regulator must decide whether to register a pesticide -- or whether to register it for some uses and not for others. A residue tax, by contrast, is a continuous variable that can be set at higher or lower levels, and that can be adjusted upwards or downwards to take account of emerging information regarding risks. A residue tax carries no absolute proscriptions, and permits individual decision-makers to decide, at the margin, whether application of the pesticide is worth the cost.

Under a crude residue tax, the total cost of the additional cancer cases attributable to a specific residue could be levied on some combination of pesticide manufacturers, pesticide distributors, and farmers if (1) the charge were levied on the total residue ultimately entering the human biomass (which can be estimated); (2) the number of cancer cases resulting from a unit of residue entering the human biomass could be estimated; and (3) the charge were levied at the time of injection into the environment rather than after time lags spread out over many years between pesticide application and entry of residue into human tissue. This approach is not without difficulties.

In principle, a residue tax should be levied on different uses of a chemical, since different uses result in varying amounts of residue entering human tissues. Imposing such a levy poses administrative difficulties because in a competitive market there is a lack of control by manufacturers and distributors over many applications; e.g., for lawns, for corn, or for fire ants. In defense of the residue tax approach, it should be noted that any attempt at selective regulation also poses a similar set of administrative difficulties. Suppose the Administrator decides to permit some uses and ban others. Then, since products containing the pesticide will still be manufactured and sold, there must be some means of policing and enforcing the rules to ensure that products are used in accordance with the rules.

The information required to impose either a crude or fine-tuned residue tax is roughly similar and equivalent to the information required for either crude or fine-tuned regulation. Viewed solely from the perspective of economic decision-making, a residue tax would appear to be a viable alternative to the direct regulation approach mandated by Congress. From a policy-making viewpoint, a residue tax poses the same type of problem as an effluent charge. These problems have been discussed at some length by Giandomenico Majone. 7/ To summarize Majone's arguments briefly, he points out that while effluent charges may appear theoretically attractive, the criteria and models used to derive or exhibit this attractiveness are typically deficient in their treatment of distributional, political, administrative, and legal issues.

The distributional problems raised by a residue tax approach are monumental. Consider, for example, the problem of compensation for damages. Under our present state of knowledge we are unable to attribute an individual case of cancer to a specific carcinogen, or to a group of carcinogens. Thus even if producers, distributors, farmers and other pesticide users could be made to internalize all costs in proportion to the precise cancer damages they had originated, the statistical incidence of, say, 5,000 cases per year could not be attributed to specific individuals whose cancer was caused by carcinogenic pesticide residues, thus making compensation of particular individuals impracticable. Hence, even if market prices could be made to accurately reflect all social costs, a serious problem of distribution and equity would remain.

Market-based theories: summary. Microscopic but widely distributed pesticide residues that are potentially carcinogenic raise issues associated with external diseconomies as well as risk and uncertainty. In the absence of any government action whatsoever, neither market prices nor other information available to consumers will reflect the element of risk. Consumers will thus unwittingly and uncontrollably subject themselves to the risk of cancer (to an unknown degree) when purchasing and consuming many foods. Chemical manufacturers, distributors of pesticides, and farmers reap the benefits of increased crop yields and profits made possible by the pesticides, while passing along to the public the increased risk of cancer, and without having to take economic account of the suffering and costs involved.

In order to preserve and improve the market as the central mechanism for arriving at social choices, several widely applicable approaches have been devised to overcome similar problems: (1) provision of more and better information to consumers; (2) legal doctrines that provide compensation to injured parties, such as negligence, absolute liability, implied warranty and strict liability; and (3) direct levies, such as effluent charges, on the emission of pollutants into the environment. For a variety of reasons, none of these represents an attractive policy for internalizing the costs that arise from low-concentration but widely distributed carcinogens. In the context of an economy that relies principally on a market-based framework of choice, therefore, the central theoretical problem is to devise appropriate decision processes that can supplement the market in generating information and drawing attention to the social costs that result from the risks posed by potentially carcinogenic residues.

The Existing Sequential Decision Process

The many inherent difficulties of relying on market-based processes to solve environmental problems were implicitly recognized by Congress when it enacted the Federal Environmental Pesticide Control Act in 1972. Instead of attempting to operate through the price system, Congress established a nonmarket regulatory mechanism which embodies (1) sequential decision making, and (2) risk-benefit analysis as the basis for regulatory decisions concerning pesticides.

The discussion of theoretical issues in this section is based on the description of the sequential decision process in Chapter 6. The present section is limited to the identification of issues arising from this sequential decision process. The next section will discuss the risk-benefit-approach as it was applied specifically to the chlordane/heptachlor suspension case, and will raise theoretical issues associated with risk-benefit analysis involving pesticides.

Provisions of the current law. A brief recapitulation of the more detailed description given above in Chapter 6 yields the following crucial decision points within the sequential decision process of EPA:

Step Number	Brief Description
1.	Registration, including reregistration of existing pesticides
2.	Monitoring of pesticides registered and in use
3a.	Convening of a formal hearing to assist the Administrator in arriving at a cancellation decision; or
3b.	Issuance of a notice of intent to cancel registration
4.	Issuance of a notice of intent to suspend registration
5.	Suspension of registration
6.	Cancellation of registration

For purposes of this analysis, we will treat decision stages 1 through 6 as components of a sequential decision-making process which gathers and analyzes information in order to improve subsequent decisions. Our general concerns here are with the cost and effectiveness of the process, and the possibility of improving it.

As was pointed out in Chapter 6, the suspension process is embedded in the cancellation process, since a Notice of Intent to Cancel must be issued before or concurrently with a suspension notice. Hence, after a pesticide has been registered and is already in use, the Administrator of EPA has the following options: (1) He can issue a Notice of Intent to Cancel, thereby triggering a formal, detailed, lengthy and expensive process of information gathering and decision making; (1a) As a minor alternative to (1), he can call hearings to help him decide on the cancellation question, without a formal Notice of Intent to Cancel; or (2) as a major alternative to (1), he can refrain from formal action and allow the monitoring, gathering and analyzing of information to continue. In order for the Administrator to issue a Notice of Intent to Cancel, he must first have developed a perception, based on a reasonable minimum of scientific evidence, that continued use of a pesticide constitutes a risk to man or the environment. Thus, stage 2 -- monitoring, gathering and analyzing of information -- is a vital link in the chain of decisions. Until recently this stage was the most loosely defined part of the entire regulatory process; a major effort is now underway to fill this gap.

Triggering of a formal cancellation proceeding. How does and how should an administrative bureaucracy go about developing a perception of risk for something like cancer, when the relevant probabilities may range anywhere between, say, 10^{-4} and 10^{-9} incidences per lifetime in the affected population? Viewed in the context of a sequential decision making process, the following issues arise:

1. What information should be collected?

2. How should the collected information be analyzed, interpreted, and translated into perceptions and thresholds of risk? It is inevitable that any information process designed to turn up indications of very low-probability risks will also produce large amounts of useless, irrelevant, or even misleading information. In communication theory this is referred to as "noise" within the system. How can the weak signals pertaining to risk be filtered out from the accompanying noise of useless information?

3. Do some organizational arrangements militate against analyzing and focusing on potential problem areas? That is, since persons responsible for detecting low-probability risk must be highly sensitive and closely attuned to the problem, how many other duties and responsibilities can they be assigned without drowning the weak signals emanating from low-probability events?

4. Can certain administrative functions associated with the detection of low-probability risks be replaced at lower cost with purchased inputs? For example, could third-party intervenors be compensated for information leading to "apprehension and conviction," such as triggering of formal proceedings that result in cancelling the registration of offending pesticides? Could this be done without, in turn, generating a flood of useless information, along with frivolous and undesirable attempts at intervention?

5. What kind of feedback mechanism should exist within the information gathering process? That is, if certain monitoring studies indicate the existence of a potential risk, should this information be used to trigger a more intensive information gathering process focused on the pesticide in question, or should a basic one-level monitoring process continue at a standard rate of intensity as the sole provider of information?

6. As evidence of potential risk accumulates, should the Administrator of EPA have other mechanisms and resources, other than triggering a formal cancellation proceeding or convening a formal hearing, that would enable him to accelerate the gathering and evaluation of information pertaining to those pesticides about which doubts have arisen? For example, should the Administrator have resources for special ad hoc studies designed to supplement information obtained from the regular monitoring program?

Answers to these questions are now emerging as a result of the recently initiated Hazard Evaluation System (HES) Program within the Office of Pesticide Programs (OPP). The HES Program has undertaken a selective survey of how hazards are evaluated in other government agencies, and has commissioned several consulting studies. One report, A Study to Develop Alternative Conceptual Approaches for a Pesticide Hazard Evaluation System, by Arthur D. Little, has become available in time for the present analysis. 8/

The interrelationship between different functions connected with hazard evaluation is shown in Figure 1, which is a slightly revised version of a figure appearing in the above consulting report. The most centrally connected box in this diagram is the data analysis to evaluate hazards. This function is connected to four separate functional loops: (a) one relates to data acquisition, processing, editing, etc.; (b) another is related to the definition of hazards and changes in standards for triggering mechanisms; (c) the third relates to construction of predictive models on pesticide applications and possible harmful impacts; and (d) the fourth is related to identification of hazards and adjustments (alternative application patterns) to reduce the hazards. At present, work of the HES Program concentrates on (a) alerting and triggering mechanisms; and (b) information/data collection, verification and analysis.

Apart from much technical detail that will be useful in day-to-day administrative applications, the Arthur D. Little report contains the following conceptual highlights that have a bearing on the nature of the sequential decison-making system employed:

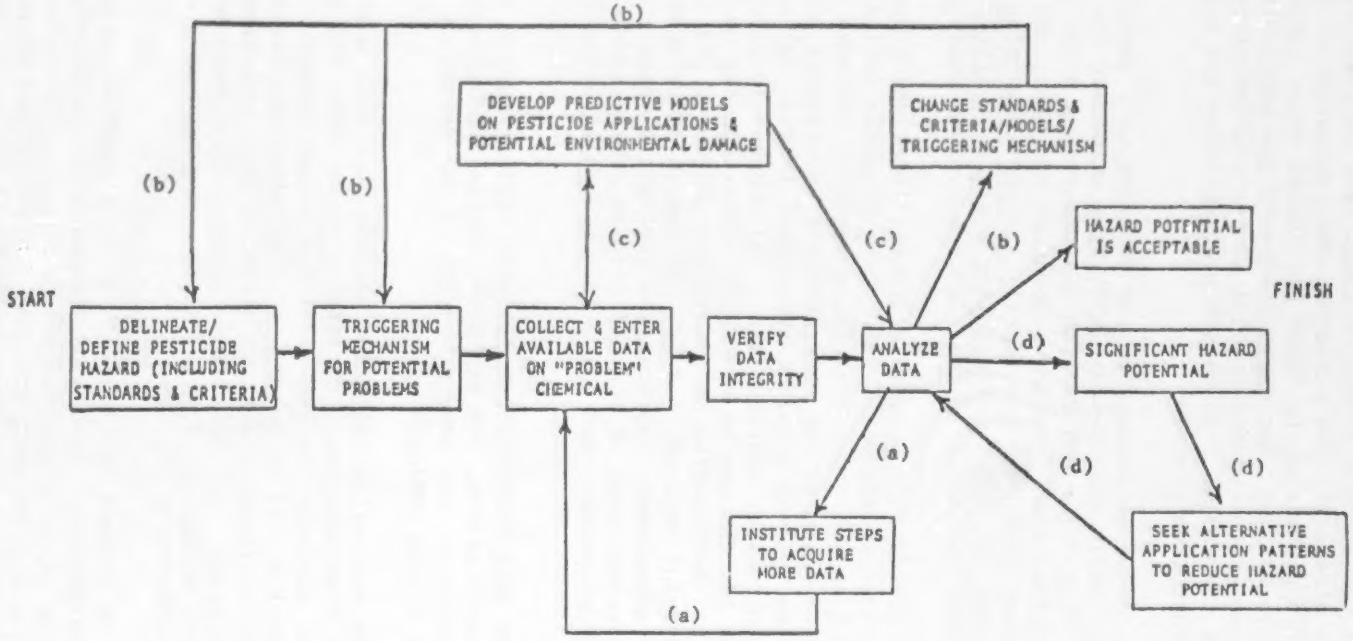
* In evaluating pesticide hazards, one must undertake a risk management decision process where the goal is to minimize the potential for future damage. This goal is one of suboptimization since the hazard evaluation function must be embedded in a risk-benefit system. The emphasis on process represents a concern for adaptation to rapidly changing and newly emerging conditions.

* The present OPP decision process operates within narrow parameters. Hazard evaluation must be undertaken in the frame of limited alternatives: (i) registering for a given use; and (ii) for pesticides already registered, cancelling or reclassifying registration,

FIGURE I.

Interrelationship Between Scientific Functional

Categories of a Hazard Evaluation System


START
DELINEATE/ DEFINE PESTICIDE HAZARD (INCLUDING STANDARDS & CRITERIA)
TRIGGERING MECHANISM FOR POTENTIAL PROBLEMS
COLLECT & ENTER AVAILABLE DATA ON "PROBLEM" CHEMICAL
VERIFY DATA INTEGRITY
ANALYZE DATA
DEVELOP PREDICTIVE MODELS ON PESTICIDE APPLICATIONS & POTENTIAL ENVIRONMENTAL DAMAGE
CHANGE STANDARDS & CRITERIA/MODELS/ TRIGGERING MECHANISM
HAZARD POTENTIAL IS ACCEPTABLE
SIGNIFICANT HAZARD POTENTIAL
SEEK ALTERNATIVE APPLICATION PATTERNS TO REDUCE HAZARD POTENTIAL
INSTITUTE STEPS TO ACQUIRE MORE DATA
FINISH
(a)
(b)
(c)
(d)

Source: A Study to Develop Alternative Conceptual Approaches for a Pesticide Hazard Evaluation System, Final Report To the Environmental Protection Administration Office of Pesticide Programs, by Arthur D. Little, Inc. Cambridge, Mass., April, 1976. Figure D.2, p. 47; as revised by OPP.

or refraining from a change. There is no option of evaluating a pesticide hazard in relation to other technically or economically feasible alternatives: for example, biological pest control methods or substitution of crops that require less hazardous pesticide applications. Yet "hazard potential" and "degree of hazard" can be adequately determined only in relationship to alternative courses of action and the values or objectives in question. 9/

* Pesticide hazards can be adequately evaluated only in the broader framework of evaluating pest management in its entirety. Such an evaluation would require that "EPA explicity acknowledge the different and sometimes conflicting values that must be balanced (economic, food, or ecological considerations) in meeting the best interests of the American public," and that it evaluate hazards "not in isolation but in comparison with, or within the context of biological, ecological, integrated, and other pest control slternatives." 10/

The evaluations of carcinogen hazards. Concurrent with the evaluation of pesticide hazards in general, EPA has initiated significant activity in evaluating carcinogen hazards that arise in all areas of concern to the agency. An internal draft document, "Interim Procedures and Guidelines for Health Risk and Economic Impact Assessments of Suspected Carcinogens" 11/ is a joint effort by several working groups, prepared in response to a special request by the Administrator. Highlights of this document are:

* It points out that evidence has been accumulating to the effect that the no-threshold concept widely accepted for cancer induction by ionizing radiation is also applicable to chemical carcinogens.

* It defines two key decision points concerning carcinogens: first, a decision whether a particular substance constitutes a cancer risk; second, what, if any, regulatory action should be taken to reduce that risk.

* It posits that the evidence for carcinogenicity will be viewed "in terms of a warning signal, the strength of which is a function of many factors including the quality and scope of data, the character of the toxicological response, and the possible impact on public health." 12/

* It recommends establishment of a Cancer Assessment Group of senior scientists within the Environmental Protection Agency, with liaison to the Department of Health, Education and Welfare. All data on potential

carcinogenicity, including data on suspect pesticides, are to be reviewed by this group.

Sequencing of cancellation and suspension. Turning our attention from the hazard monitoring and evaluation stage to the cancellation and suspension proceedings, it is recalled from Chapter 6 that different criteria are used for the various decisions involved. A Notice of Intent to Cancel triggers the most expensive and time-consuming information gathering process available to the Administrator. The ultimate decision that can result from a cancellation process is, in keeping with its high cost in terms of both money and time, the most drastic: permanent cancellation of the pesticide's registration. At the same time, issuance of this notice is triggered by the lowest threshold of perceived risk. The only requirement is for some scientific evidence that a pesticide (or its metabolites) may be carcinogenic.

If the Administrator also perceives that the risks associated with a pesticide are such that continued usage presents an immediate hazard, then a Notice of Intent to Suspend will initiate an expedited and less expensive information-gathering process. The most restrictive action that can result from this information-gathering process is a temporary suspension of registration pending the outcome of the cancellation proceeding.

Thus the cost of the information process used to reach a decision about suspension or cancellation varies in proportion to the gravity of the actions that can result from the process. The cost of the information-gathering process triggered by a suspension or cancellation notice varies inversely with the urgency of the perceived risk; i.e., those risks perceived to be more urgent trigger a less costly information gathering process. Viewing the existing process as one of sequential decision making raises the following questions.

1. If one were designing an optimal decision process, would it be appropriate for the less urgent risks to lead directly to the most intensive, time-consuming and expensive information-gathering process? As an alternative should an expedited and less costly suspension hearing always precede a cancellation hearing? On the basis of such a hearing the Administrator could make a concurrent decision whether to suspend and/or proceed with a full-scale cancellation hearing. The public record assembled during a suspension hearing could then be used to facilitate any subsequent cancellation hearing. If the suspension hearing preceded a cancellation action, it could be modified by new legislation to lead to a less drastic terminal action than eventual cancellation. For example, some uses of a pesticide could be restricted with regard to the amount injected into the environment; other uses could be made conditional on special crisis situations, such as a predicted cutworm infestation of the corn crop in a particular area. This opens up a promising direction for new policy initiatives.

2. Instead of going directly into a formal suspension hearing, should the Administrator perhaps have available to him some other intermediate decision process (it could be adversary or non-adversary) in which manufacturers and other interested parties might be invited to participate? At present, certain alternatives do exist, but each one has certain limitations:

    a. Issuance of a Rebuttable Presumption Against Registration (RPAR) initiates an information gathering process, but it applies only to pesticides awaiting registration or reregistration. Moreover, issuance of an RPAR does not involve a lower level of hazard than denial of registration; it serves simply as a way station to the latter, more drastic step. 13/

    b. The 1975 legislative amendments to FEPCA 14/ provide for consultation with the Secretary of Agriculture and with a specially created Scientific Advisory Panel prior to issuance of a notice of intent to cancel or reclassify the registration of a pesticide. This process tends to serve only as a way station to stronger action rather than as an intermediate decision process that operates at lower levels of perceived risk.

    c. Convening of a formal hearing under Section 6(b)(1) of the law, to help the Administrator determine whether to proceed with a formal cancellation notice.

   The two processes both lack an appropriate, milder form of remedy -- such as restriction of the total amount of the pesticide that can be released into the environment in any given area, over a given time period -- short of suspension or cancellation. Instead, these "intermediate" processes either abort altogether or proceed inexorably toward a cancellation notice, a remedy perhaps too drastic in relation to the perceived level of risk.

The end result of any regulatory decision process concerned with carcinogenic risks must allow for cancellation of a pesticide's registration as one course of action. This is the most complete and permanent remedy available. It is appropriate, therefore, that the most intensive information-gathering process should precede invocation of this remedy. Also, due process of law under our constitution necessitates that this final stage be conducted as an adversary process, with the advocates of continued registration given a fair hearing. Abstracting from this legal perspective and viewing the existing process as one of information gathering and sequential decision-making raises some interesting theoretical issues. The sequential decision process discussed in this section embodies, under the law, a component of risk-benefit analysis, the subject to which we now turn.

Risk-Benefit Analysis

Congress has made the balancing of risk and benefits the key criterion for decisions along the various lines of the existing sequential decision chain. This section deals with some of the theoretical issues raised by this fundamental risk-benefit issue.

Estimating magnitude of the risk. When the probability of an occurrence is small -- somewhere in the range of 10^{-4} to 10^{-9}, for example -- it is extremely difficult to develop an estimate which one feels is correct within one or two orders of magnitude. It is entirely possible that there may not even be one observed occurrence of the event over a period of many years. In the nuclear fuel cycle, for example, no nuclear generator has ever experienced a core meltdown, yet the Wash-1400 Study had developed a decision-tree approach for estimating the probability of a core meltdown. It is not necessary to agree with the estimated probabilities in order to appreciate that the estimation procedure is based on a method which, although extremely complicated and somewhat debatable, is at least sufficiently objective to permit analysis and criticism by others who have an interest in the issue.

In the area of pesticides and the risk of cancer, even the beginnings of a comparable estimating procedure are lacking. While 10^{-4} and 10^{-9} are both small numbers, there is a vast difference between the two. One expert witness during the chlordane/heptachlor suspension hearing noted that if the probability of developing cancer from pesticide residue were 10^{-4} incidences per lifetime, the application of this probability to a population of 200,000,000 would result in 20,000 additional deaths from cancer (rather than from other causes). This calculation, while clearly correct, was simply put forth as an arithmetic exercise by the witness, who was not willing to state that in his professional judgment the best estimate of the probability was indeed 10^{-4}.

The preceding exercise can be extended to state that a probability of 10^{-6} implies only 200 additional cancer deaths in a population of 200,000,000, and a probability of 10^{-8} implies only 2 cancer deaths. In view of the fact that over 50,000 die each year in automobile accidents, 2 deaths would not rank high on a list of social hazards, whereas 20,000 deaths would rank quite high. The issues which this arithmetic exercise raises are: What is a good professional judgment concerning the correct probability? On what is such judgment based? Can one develop a more objective means for estimating the probability of developing cancer caused by pesticide residues?

A risk-benefit model for pesticide-induced cancer. There appears to be a rather sharp contrast between the expanding body of detailed data relating to pesticide residues, and the lack of any formal risk-benefit model for utilizing such data as they accumulate. The contrast with studies of atomic risk is striking. Those concerned with risk-benefit analysis for atomic reactors have constructed an enormously detailed and elaborate risk-benefit model (in the Wash-1400 study), but in the area of potentially carcinogenic pesticides in humans, there appears to be no formal risk-benefit model whatsoever. Considerable data were introduced into the record concerning the amount of pesticide residue which the monitoring program had found deposited in various parts of the human body, such as the liver, spleen, or adipose tissue (see Chapter 7 for more details). Yet there was, and is, no complete model for assessing the risk of cancer, a fact which, at least indicates the extent of the gaps in our knowledge. To be sure, the various scientists who testified for both the government and the manufacturer of chlordane and heptachlor were all very careful not to overstep scientific boundaries of knowledge and draw any unwarranted conclusions from these data. The point is, even an expedited hearing accumulates large amounts of highly technical data, and in a full cancellation proceeding still more data are submitted. At present there appears to be no method (other than common sense) whereby the judge can systematically assess such volumes of data. A formal model, to take account of and put into perspective the many branching possibilities would appear to be a useful contribution (such a model would be similar, in broad outline, to the Wash-1400 model).

We suggest that a multidisciplinary effort to specify and develop a preliminary but formal and detailed model would represent a worthwhile contribution, even if the first such model were highly tentative. As with the Wash-1400 model, there exists a greater number of potential branches to be specified and quantified. If nothing else, such a model could help focus attention on a number of interesting and important questions which biological scientists might otherwise overlook. The following are of particular interest: (1) How long do various residues and their metabolites persist in humans, i.e., how long is the half-life of the various residues in human tissue? (2) How powerful a carcinogen is each of the various residues and its metabolites? Is it feasible and worthwhile to construct a scale which measures the relative strength of various carcinogens? (3) Do residues have a tendency to concentrate in certain organs or do they spread uniformly throughout the body? (4) Does the concentration in various organs make any difference? That is, do some organs develop cancer more readily than others? Only the answers to questions such as these, obtained under varying circumstances of exposure, will clarify the carcinogenic hazards of given dosages to persons with different life circumstances, by age, sex, degree of physical activity, general health and exposure to other harmful substances and conditions.

Data from animal experiments. At present, owing to the infeasibility of epidemiological studies 15/ (discussed in Chapter 7) and the absence of any formal risk-benefit model of cancer in humans (discussed above), animal experiments are the only way of assessing the carcinogenic hazards of toxic substances such as pesticides. The theoretical problems raised by such experiments have been discussed exhaustively elsewhere. The chlordane-heptachlor suspension hearings cited some of this evidence, 16/ which was presented on the basis of both published and unpublished materials and further developed by witnesses on direct and cross examination. The main issues are:

- Statistical extrapolation from high dosages needed to get measurable results in animal experiments, to the much smaller doses that pose environmental hazards in reality.

- The feasibility of measuring such effects directly by greatly increasing the number of experimental animals used.

- Interaction between separate carcinogenic substances that may increase the hazard far more than in a simple additive way.

- Extrapolation of results from experimental animals to man.

- The social distribution of costs and benefits.

The main unresolved problems are summed up in the following passage, representing the views of researchers who have done some of the historical work in the field: 17/

> Where does all this leave us?
>
> It leaves us able to develop rather good animal data at dose levels that do not really interest us. That is a first-class highway that takes us where we do not want to go. It leaves us unlikely to be able to develop good data at "realistic" doses. To extrapolate animal results to man exposed at these "realistic" doses today requires assuming a mathematical model of dose-response in the animal and conservative use of this model. Then we have to jump from one species to another in ignorance of the terrain of the landing site, i.e., the many species differences. However, we will have knowledge of some important special similarities and are just beginning to understand some of the implications of the arithmetic. We have begun to see that there are few, if any, good ways of totaling the costs or computing the benefits. Cost-benefit may be another blind alley.
>
> Tomorrow and the next day we must do the appropriate research on species differences in metabolism and in the mathematics of the modeling and extrapolations -- as a minimum. The socially related issues, such as what is an acceptable risk, what are the costs, what are the benefits, must be discussed in the open, freely. This implies recognizing that someone's costs may be someone else's benefits. (Our medical costs are our physician's source of living.) The inputs to the cost-benefit algebra are not well worked out. Our ways of working must include the adversary approach as well as the pleasanter way of

> cooperation. And today, we must get to precautionary decisions for man's safety -- inadequate as they are.

The gap between dosage response data and a complete system model. The previous section detailed the uncertainties of assessing carcinogenic risk based on data describing the biological response to known dosages under controlled circumstances. There is, however, a broader problem, of which dosage response is only a part. Given the discharge of specified amounts of toxic substances into the environment, we need to know the answers to a series of questions such as: (1) How long do pesticide residues and their metabolites persist in the environment under various conditions? e.g., in the soil? in runoff into streams, lakes, estuaries and the ocean? in the air? in plant and animal tissues along the various links of the food chain? (2) How are pesticide residues and their metabolites distributed by various convection routes from their points of entry into the environment? (3) Where and under what conditions are different concentrations of potentially carcinogenic substances generated? (4) What are the routes of entry of such substances into normal tissues and the resulting concentration in the tissue?

This is the point at which dosage response information becomes extremely relevant. We suggest that future work along these lines might attempt to throw more light on specific response mechanisms, with the ultimate aim of developing a complete system model which would (1) make good use of all available data, and (2) demonstrate the extent of the gaps in our existing knowledge.

Alternative pesticides vs. alternative uses of land. Cancellation or suspension proceedings are typically initiated against one or two pesticides at a time. This means that in practice the risk-benefit analysis is applied against the assumption that the use of all other pesticides is unaffected. There is thus an underlying confidence that subjecting potentially dangerous pesticides to analysis, one or two at a time, and taking action where warranted, will make the situation better, rather than worse. Because of the way in which the analysis is applied, this assumption may be incorrect, for the following reasons.

The law stipulates that the criterion for cancellation and suspension is an "unreasonable adverse effect on the environment," which is defined to mean "any unreasonable risk to man or the environment, taking into account the economic, social, and environmental costs and benefits of the use of any pesticide." 18/ Beyond this statement, no particular risk-benefit model is specified, and in the case of chlordane/heptachlor the Administrative Law Judge did not stipulate that he was using any particular model or that he was looking for any particular evidence. Both sides presented evidence on the risk, costs, and benefits as they saw fit. Despite the absence of any particular model specification, and from the admissibility of isolated individual pieces of evidence in the administrative law proceedings, it is nevertheless possible to infer an implicit model that was being employed. Two factors stand out.

First, all the major uses and applications of chlordane and heptachlor were considered in some detail; alternative pesticides, effective against the same pests, were explicitly brought into the analysis. The central thrust of this analysis, however, was on the cost and effectiveness of other pesticides: the cost per application and the number of applications necessary in order to achieve the same effect as chlordane or heptachlor. *The possible problem of residues and potential carcinogenicity of other pesticides was not raised as an issue*, unless the other pesticides were already the subject of a cancellation or suspension proceeding (e.g., mirex, which is a substitute pesticide for some uses, was the subject of a concurrent cancellation proceeding). Thus the costs and benefits, but not the *risks*, of other pesticides were being compared with the costs, benefits *and risks* of chlordane and heptachlor.

The chlordane and heptachlor case shows that EPA's decision process might well be described as "sequential suboptimization." There is an implicit faith that this step-by-step process will in time lead to an optimal situation. This assumption is not altogether unreasonable, especially if the decision process is reversible; that is, if a previously banned pesticide can be reconsidered on its merits at a later date. In theory such a reversibility could occur. Given the ponderous nature of the present process, however, one wonders whether subsequent reconsideration is likely ever to occur.

Second, partly as a result of the extensive discussion about the availability and effectiveness of substitute pesticides, there appeared to be a tendency to evaluate the suspension of chlordane and heptachlor only under the limiting assumption that farmers would continue to grow the same crops, and would use alternative pesticides or pest control procedures. Some evidence was entered into the record concerning other crops that could be grown with no pesticides whatsoever, or with entirely different pesticides designed to control other pests (e.g., the corn cutworm, against which chlordane and heptachlor are effective, would not be a problem if the farmer switched to something like soybeans or sugar beets). The Administrative Law Judge gave some consideration to these alternatives in his recommended decision. The lengthy discussion accompanying the final order by the Administrator, however, while discussing at some length the availability of other pesticides for the same crops, completely disregarded the possibility of growing entirely different crops on land currently treated with chlordane or heptachlor. 19/

The underlying model specification was thus, predominantly, one of subsystem -- or, in economists' terms, partial equilibrium -- analysis. In considering the effects of an intervention in the operation of market forces, attention centered on direct effects, to the almost complete neglect of indirect effects brough about by second and higher-order adjustment processes. There is no need to review here the voluminous literature that exists on risk-cost-benefit analysis. 20/ The theoretical and practical issue is whether EPA should develop a more formal and sophisticated risk-benefit-cost model for use by its Administrative Law Judges and attorneys for both sides. Such a model would specify the treatment of other alternatives like those discussed here.

The issue of "horizontal" equity. As noted previously in Chapter 3 (see page 16), there is a widespread argument for neglecting distributional effects in benefit-cost analysis on the basis that the effects of the particular project under consideration are distributed in the population independently of the marginal social value of a dollar. This argument, which is equivalent to assuming that there are no distributional effects, refers to what is sometimes called "vertical" equity.

The issue raised by pesticide cases like chlordane/heptachlor relates to the income of a particular group of farmers who depend heavily on a specific pesticide for the success of their crops. 21/ The literature on cost-benefit analysis contains numerous discussions on compensation principles and the willingness of individuals in society to pay others for actions which benefit them. The fact is, however, that the law currently provides no compensation whatsoever for those who may be adversely affected by a regulatory decision. Issues raised by this state of affairs are:

1. Should there be some form of compensation under certain conditions? If so, should such compensation be based on an inherent general or limited "right to pollute?"

2. If compensation is warranted, how much should be paid, and what principle(s) of compensation should be used to determine the amount?

3. If one holds that those who are adversely affected should not be compensated, what is the theoretical justification for this position?

In the chlordane/heptachlor suspension case the final order of the Administrator made some allowance for the hardships which suspension would cause by (1) permitting stocks in existence to be used and (2) postponing the effective date of suspension for use on corn.

Monitoring and enforcement costs. As noted above, administrative law proceedings do not incorporate any kind of formal cost-risk-benefit model. An implicit model can be inferred to a degree, from the testimony offered. It is interesting that in the case of chlordane/heptachlor the final order issued by the Administrator called for restricted use of both pesticides, rather than a complete ban. Presumably, therefore, products containing chlordane and heptachlor will continue to be manufactured and sold. Some enforcement of the selective restrictions may thus be necessary. Nowhere in the record, however, were the cost, problems, or efficacy of enforcement discussed. A number of issues are raised:

1. How much is budgeted for enforcement and policing of pesticide regulations and restrictions?

2. How effective is enforcement and policing? i.e., to what extent will restrictions like those contained in the Administrator's order be, in fact, observed?

3. Comparing a complete ban (which is relatively easy to enforce) with an order for restricted use, what

additional costs for policing and enforcement are implicit in the restricted order?

4. What implicit assumptions regarding policing and enforcement were made by the Administrator when he decided to issue an order for restricted use? How valid are these assumptions?

Dynamic Considerations

The entire regulatory legislation, described earlier in terms of the six stages of the existing sequential decision process, is focused on chemical pesticides already in existence and on new chemical pesticides which manufacturers elect to submit for registration. This six-stage process is not — and should not become -- a thing unto itself, as are so many of our other regulatory processes. The pesticide regulatory process is part of and is inseparable from our total technology.

The real world is not static but dynamic and the model used for analyzing the total regulatory process should also be dynamic. We should, at a minimum, enumerate specific dynamic considerations and then analyze whether the approach to decisions under risk adversely affects the dynamic considerations. Some relevant dynamic considerations are the following:

1. Development of new chemical pesticides. Does the regulatory process impede or inhibit the development of new and better pesticides? Also, will it in part redirect R & D toward desirable defensive research and the development of less hazardous substitutes?

2. Entry of new firms. Does the regulatory process impede the entry of new firms into the chemical pesticide business, thereby limiting or restricting competition?

3. Development of other pesticide control techniques. Does the regulatory process have the effect of directing research and development towards other, non-regulated pesticide control techniques?

4. Adoption and implementation of integrated pest control methods, and other pest practices. What is the effect of the regulatory process on the development of ecologically sound land utilization, food production and energy conservation methods at the level of society as a whole? Does it move us in the direction of social optimality in the large, or does it bog us down in penny-wise and pound-foolish arguments over severely limited options?

The discussion of such dynamic considerations raises a series of questions that are more general than the theoretical issues we have been focusing on thus far. These questions are inseparable from the broader social policy alternatives with which this study is concerned.

Summary

The basic legislation that established the present regulatory framework has been described, but there has been no attempt within the scope of this study to investigate or analyze the political bargaining process that accompanied the enactment of this legislation. The registration portion of the regulatory process has also been described briefly but not analyzed. The focus of this case study is on the adversary proceedings which take place when the registration of a pesticide is challenged. Using the chlordane/heptachlor suspension case as our benchmark, this chapter has reviewed alternative ways of making social decisions about continued uses of a pesticide under conditions of risk and uncertainty.

In particular, market based approaches to decision making have been reviewed and contrasted with the present regulatory approach. The major challenge facing any decision process is the substantial lack of information regarding the existence of pesticide residues in both the environment and the human biomass. Basic information and knowledge in this area can be generated only by continuous monitoring and research efforts: it will not result from the usual interplay of market forces. Hence government-sponsored monitoring and research on pesticide residues is seen to be essential.

Once the basic monitoring information is in hand, alternative approaches to social choices are available. The two major decision approaches discussed here -- market and regulatory -- both suffer from a lack of clear signals as to what action ought to be taken on the basis of the fragmented information available. The chlordane/heptachlor case raises a substantial number of unresolved theoretical issues, all of which provide fertile ground for additional research aimed at improving the existing decision process.

In the next chapter, we will examine the pesticide decision process in a broader context. In Chapter 10 this process will be evaluated in terms of the criteria developed in Part I of this study.

Notes to Chapter 8

1. For an elementary and highly readable exposition, see Robert L. Heilbroner, The Economic Problem (Englewood Cliffs: Prentice-Hall 1972). The standard exposition at an advanced level is Gerard Debreu, Theory of Value: On Axiomatic Analysis of Economic Equilibrium (New York: Wiley, 1959). For a critique, see Janos Kornai, Anti-Equilibrium; On Economic Systems Theory and the Tasks cf Research (New York: American Elsevier 1972).

2. This means that, contrary to the basic assumption of the theory that organized markets exist at all times for all commodities, markets "fail to exist" for part of the consequences of some actions. In other words, the theory assumes that all economically significant influences within the system are transmitted between participant firms and households in the form of competitive commodity exchanges; yet in fact, some of these influences "fail" to appear in the form of commodities traded in competitive markets. External economies and external diseconomies are, then, economic effects which bypass market channels.

3. See: Kenneth A. Arrow and R. C. Lind, "Uncertainty and the Evaluation of Public Investment Decisions" American Economic Review (June, 1970); Jack Hirschleifer, "Investment Decisions Under Uncertainty: Application of the State Preference Approach" Quarterly Journal of Economics (May 1966).

4. See K. Lancaster and R. Lipsey, "The General Theory of the Second Best" Review of Economic Studies, Vol. XXIV (1) No. 63, pp. 1-18.

5. Recent studies of products liability insurance have shown, however, that less constructive adaptations may also occur. For example, firms may break up their operations which are at risk into small legally independent units, each of which can be abandoned to bankruptcy in the face of a large lawsuit. This practice is already common in the case of New York City taxicab fleets, where each cab, for legal purposes, franchises as a separate corporation.

6. The risk may be uninsurable at any reasonable level of premiums, as has recently happened to medical malpractice insurance. The so-called "products liability problem" arises from the fact that the doctrines of strict liability and implied warranty create tort liability exposure to individual firms that in extreme cases can exceed their net worth many times over. For example, manufacturers of machine tools whose products are still in use thirty or forty years after the original sale — and this is quite common — find that the new legal interpretations saddle them with a huge backlog of tort liability exposure that cannot possibly be handled under commercial insurance practices. Even in less extreme cases, the rates have risen sharply and insurance sometimes becomes unobtainable.

7. Majone, Giandomenico, "Choice Among Policy Instruments for Pollution Control" Policy Analysis (1976) pp. 589-614.

8. U.S. Environmental Protection Agency, Office of Pesticide Programs, A Study to Develop Alternative Conceptual Approaches. . ..

9. U.S. Environmental Protection Agency, Office of Pesticide Programs, A Study to Develop Alternative Conceptual Approaches. . ., p. 41.

10. U.S. Environmental Protection Agency, Office of Pesticide Programs, A Study to Develop Alternative Conceptual Approaches. . ., p. 43.

11. U.S. Environmental Protection Agency, *Interim Procedures and Guidelines for Health Risk and Economic Impact Assessments of Suspected Carcinogens* (Washington, D.C.: May 13, 1976).

12. U.S. Environmental Protection Agency, *Interim Procedures and Guidelines. . .*, p. 4, emphasis added.

13. See Chapter 6, subsection: "Current legislation concerning pesticides," Item 1(c), p. 49.

14. 94th Congress, Public Law 140, 89 Stat. 751, 7 U.S.C.S. Sects. 136-136b, 136p, 136w, 136y, November 28, 1975.

15. See Chapter 7, Section: "Evaluating the Risk of Cancer," second paragraph, p. 64.

16. See references cited in Chapter 7, Notes 13 and 17.

17. Schneiderman, "From Mouse to Man. . ."

18. See Chapter 6, subsection: "Current legislation concerning pesticides," 2nd paragraph, p. 48.

19. U.S. Environmental Protection Agency, Suspension Proceedings Before the Commissioner, *Decision of the Administrator on the Suspension of Heptachlor/Chlordane*, and U.S. Environmental Protection Agency, Before the Commissioner, *Recommended Decision*, p. 86.

20. Some of the more important references used in this study are included in the bibliography.

21. Pesticide decisions inevitably impact certain geographical areas and parties. To the areas and parties affected, these impacts are often major. At the same time, aggregate impacts -- that is, impacts on commodity prices and consumers -- may be quite small. Thus, issues of horizontal equity are pervasive and inherent in pesticide decisions, while issues of vertical equity may be so minor as to be almost nonexistent.

9. Broader Issues Concerning the Pesticide Decision Process

The discussion in Chapter 8 emphasized those aspects of the decision process that fit into one particular overall view of reality: it surveyed the approaches of neoclassical theory to the problem of decision-making under risk, analyzed some aspects of EPA's sequential decision-making process, and reviewed the risk-benefit approach embedded in this sequential decision-making process. For lack of a better label, we shall designate that viewpoint as the "optimization" paradigm. 1/

The total decision process is somewhat broader than the methodology for optimizing costs, risk, and benefits. Other approaches to the pesticide decision process which are at least as important, perhaps more so, are examined in this chapter. The optimization paradigm of Chapter 8 will be compared and contrasted with one alternative view of reality, the "legal" paradigm. This introductory discussion puts the optimization paradigm in perspective and highlights the importance of using a socially acceptable process to make important decisions and social choices (for more extensive discussion on this particular point see Part I of this study).

The legal process as a vehicle for decision-making under risk has, in recent times, been criticized by many scientists who feel that better ways to marshal and weigh scientific evidence can and should be developed. In view of this concern by the scientific community, this section includes a brief examination of some alternative legal procedure which might be more acceptable to them, as well as a brief rationale for each suggested alternative. The purpose of this discussion is to develop a broader understanding of the decision process as it relates to pesticides. The concluding chapter will then evaluate the existing decision process in terms of the criteria presented in Part I of this study.

Alternative Paradigms for Decision-Making Under Risk

The process of arriving at social decisions in situations involving low-probability high-consequence outcomes involves people from a number of disciplines and backgrounds; each brings his own view of reality to the decision process. In the legislative part of the process, exemplified by enactment of the FIFRA legislation, an important view of reality is that held by the political scientist, or what might be called the "political" paradigm. 2/ This viewpoint is downplayed here only because this case study is focused on that part of the decision process which follows enactment of the legislation.

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Current legislation requires that the Administrator of EPA take account of the risks and benefits of continued use when deciding whether to continue registration of a pesticide. The law does not require that pesticide cases specifically employ an optimizing cost-risk-benefit model, but intent seems implicit. At the same time, the FIFRA legislation also requires that the risks and benefits be considered within the framework of an administrative law proceeding. The optimizing and legal paradigms thus represent the two major approaches embodied in the current pesticide decision process.

The optimization paradigm. This paradigm might best be characterized as oriented to the modeling of current decisions about future situations, while the legal paradigm is oriented more to a process for resolving past disputes and incorporates a strong emphasis on precedent and authority. As applied to risky decisions, the optimization paradigm attempts to identify whatever information is available for dealing with a problem, and then within the constraints of that information hopes to find a way to reach the best possible decision. Of course, this decision need not be optimal in its actual outcome when the outcome itself is probabilistic; it is required to be optimal only in the sense that, under the given circumstances, the expected payoff is being maximized. 3/

Approaching problems within the context of this optimization paradigm requires that all major factors pertinent to the final decision be quantifiable. The optimization approach then operates within the broad outline of the cost-risk-benefit calculus. Important nonquantifiable factors, such as the dynamic considerations discussed in Chapter 8, are typically not included in the formal model; more often than not, they are deemphasized or omitted altogether from the analysis. The cost-benefit model can theoretically be expanded to include a comprehensive systems approach, as in a total ecological system, but the model that is actually used for a specific problem often represents a subsystem of some broader unspecified system. Thus specific applications of this optimization approach may vary quite widely, from one case to the next, depending upon the viewpoint of the analyst and the possibilities of measurement.

Risk analysis may range from an elaborate and extensive formal model like that contained in the Wash-1400 study 4/ (the Rasmussen Report) to no more than a professional judgment by a technical expert. The optimization approach attempts to arrive at a single solution, based on maximizing one specified objective function. While multiple objectives may be contained in a composite objective function, for the most part the optimization paradigm attempts to offer a unifying approach. It is oriented neither to conflict, especially deep-seated conflict, nor to the resolution of conflict.

The legal paradigm. The legal outlook, in contrast, embraces the realization that a given set of facts can be interpreted from at least two (or more) contradictory angles. This approach is more open to perceiving a problem in its entirety, albeit in a less formalized setting. As applied to decisions involving pesticide risks, this approach recognizes the tremendous information gap which characterizes any individual decision, and does not necessarily aim at making individual decisions in some sense "perfect". It is concerned more with what can be reasonably said to be true about a particular situation than with what the abstract truth of that situation actually might be. In other words, it concentrates on pesticide decisions as a stream of human activity involving much uncertainty, many interests in partial or total conflict, many independent or conflicting value orientations among participants, and the impossibility of making, in any sense, a "perfect" decision in a given case. 5/ In each specific case the legal process reaches a decision by applying known rules of law to facts admitted under the established rules of evidence (and only to those facts).

An essential consideration is the formation of a social consensus that emerges as a result of the tugging and pulling of the long-term, repetitive legal process. At the end of this process, individual participants may feel unsatisfied with particular outcomes, but they will usually also feel that they have had their "day in court" and therefore are generally more willing to accept a somewhat adverse outcome. If the legal approach is established within an executive agency, as was done with pesticide regulation, the ultimately political nature of any regulatory decision making process is stressed, therefore necessitating the clear identification and political accountability of the final decision maker. 6/

Comparison of the two viewpoints. The optimizing and legal paradigms both represent cognitive approaches to find the "best" choice in a given situation, but there are some fundamental differences between the two points of view. Persons trained in these contrasting ways of thinking may have difficulty communicating with one another. Fine lawyers sometimes feel uncomfortable resting their cases on risk-benefit calculus. Conversely, many scientists -- and this emphatically includes some economists -- are not comfortable thinking in terms of social process and conflict rather than in terms of optimizing choices. 7/

Although the preceding description stressed differences between the optimizing and legal approaches, these two viewpoints are not mutually exclusive, nor do they represent opposing viewpoints. Instead, their differences make them complementary, and the present decision process can be viewed as an attempt by Congress to combine the two paradigms into a unified decision process. That is, the optimization paradigm (cost-risk-benefit analysis) is embedded within the adversary process used for cancellation and suspension proceedings. This legal approach in turn reflects our political process, which provided the authorizing legislation.

An appraisal of EPA's sequential decision-making process must be capable of embodying not only these two points of view, but others as well. 8/ Procedures which might otherwise seem hard to justify suddenly come to life when one switches from one point of view to an entirely different one. This is particularly important in light of Congress' recent concern for opening up the EPA decisionmaking process to more public participation, especially to agricultural interests 9/ which have seen many recent EPA decisions go against them.

Another important viewpoint affecting the legal process used in pesticide cases is the scientific viewpoint. This might best be characterized as oriented to the accumulation of knowledge and the drawing of logical inferences where possible, coupled with the abstention of inference and retention of an open mind when inferences can not be supported by facts and experimental evidence. 10/ The scientific viewpoint, with its strong emphasis on rationality, is not really a social decision process; its presence is nonetheless strongly felt in pesticide cases.

An article by Philip L. Spector, "Regulation of Pesticides by the Environmental Protection Agency" 11/ contrasts the views of scientists on the one hand with those of lawyers on the other hand -- all within EPA. Spector avers that lawyers, clustering around the Office of General Counsel, are in general more environmentally activist than scientists associated with the Office of Pesticide Programs, but our own interviews within the Agency found strong dissent with this point of view.

Spector's allegation is certainly too broad. Scientists do appear on different sides of environmentally relevant issues, but as a group they cannot be characterized as less committed to the environmental protection principle than lawyers. Spector bases his point on the reluctance of scientists to commit themselves to the defense of the hypothesis that a particular pesticide is harmful, unless there is compelling evidence to support such a view. He fails to state, however, the corollary that scientists are equally reluctant to commit themselves to the hypothesis that a pesticide is harmless unless there is evidence to support that particular statement. In between there is an enormous range of cases where the evidence supports neither the original statement nor its converse. Scientists -- as scientists -- are neutral between hypotheses; they judge only the quality of support.

Aside from Spector, a great deal has been written about both the scientific and legal method, but to our knowledge the similarities and differences between the scientific and legal viewpoints have nowhere been carefully drawn. Similarities center around the fact that both processes attempt to derive valid conclusions from factual evidence. Legal and scientific methodology each operate within a broad framework, yet each is capable of and attempts to tackle a specific problem on its own individual merits. In this broad sense the two processes appear complementary. But certain differences also deserve mention. One is that development of the legal process was centered for hundreds of years around cases that pertained solely to past events, such as crimes or civil cases like breach of contract. Thus both criminal and civil rules of evidence were designed primarily to help determine the pertinent "facts" related to some prior incident or act. In other words, legal rules of evidence were not developed for the purpose of marshalling and interpreting information to assess the possibility of future occurrences. 12/ In the case of risk, however, such as pertains to pesticide decisions (and in other areas beyond the scope of this case study), this is precisely the use to which the legal system is being put. 13/

A second difference concerns the strong underlying orientation of the legal process toward reaching a decision. For this reason, in the legal process (and, for that matter, in other decision processes as well) inferences must often be drawn from fragmentary and inconclusive data. Lawyers are trained to prepare their case, present the best evidence available and then drive towards a resolution of those matters that require decision, one way or another. The length of time required to try a major legal case does not alter the existence of this basic drive towards a final decision. Scientific training, by contrast, leads one to reject any unwarranted inference and instead seek more information. A truly scientific outlook motivates one to indicate the limits of knowledge and lay out research aimed at adding to our base of knowledge. Courts (and other decision making bodies) focus on reaching "fair", "just", or "acceptable" decisions, one way or another, and the decision process itself typically exhibits relatively little interest in developing proposals for further inquiry. 14/

Alternative Legal Procedures

The preceding discussion has again focused on differences while glossing over the main similarities between the scientific and legal viewpoints. How critical the differences are between these two viewpoints is unknown, but from time to time a number of scientists have expressed dissatisfaction with the way in which our existing decision processes marshal and interpret scientific evidence on technical issues. This dissatisfaction has led some concerned scientists to recommend the establishment of an entirely new institution, usually referred to -- for want of a better name -- as the "Science Court." 15/

It is not our purpose here to evaluate or enter into the debate over the need for, or merits of, a Science Court. The fact that a number of scientists have expressed so much dissatisfaction with the existing decision process may, however, indicate a gradual but steady erosion of the ability of the process to forge social consensus on crucial issues. It is of supreme importance that the process not lose the support of a major influential group such as the scientific community. For this reason, the issues posed by proponents of a Science Court need thorough airing. In particular, alleged shortcomings of the existing legal process need to be clearly enunciated, and alternatives aimed at overcoming any generally agreed-upon shortcomings need to be developed and evaluated. The Science Court is but one of many alternative reforms that could be adopted. Within the scope of this case study it is not feasible to undertake a complete critique of existing legal procedures as they are applied to decisions involving determination of scientific "facts", as in a pesticide case. On a more limited scale, though, we have explored a few possible changes which could be made in the legal procedures used to gather and interpret scientific data that are deemed relevant to risky pesticide decisions.

It is recognized that EPA has no authority to change the administrative law practices which are prescribed and followed in cases involving the suspension or cancellation of pesticides. Only Congress can change the law. The purpose of this discussion is not to criticize EPA, but to suggest some explicit alternative procedures. These are raised as topics for discussion only. Their mention is not intended to recommend them, nor even to indicate that we regard them as desirable.

Revise the role of the expert witness. In a legal proceeding a person who qualifies as an expert witness is permitted to play a somewhat privileged role. In particular, professional opinions of expert witnesses are allowed to enter the trial record as evidence, whereas other witnesses are not permitted to express opinions as part of the record. Thus in a trial proceeding expert witnesses are in a position to play a differential -- and perhaps crucial -- role. Due to the importance of this role and the potential influence which an expert witness may have on the outcome of the case, lawyers sometimes expend considerable effort in establishing or attacking the credentials and credibility of proposed expert witnesses.

An interesting feature about expert witnesses is that the law does not provide for any gradations of expertise: a person either qualifies as an expert witness, or he does not qualify. (In pesticide cases it is typical for a majority of the expert witnesses to be natural scientists, most typically from the biological sciences.)

This legal tradition for building up evidence about a case by use of opposing expert witnesses is somewhat at variance with scientific tradition. A purely scientific debate typically leaves little room for opinions (other than theories, where theorizing is necessary). Emphasis is placed instead on experimental procedures (controls, accuracy of measurement, etc.), findings, interpretations of data, and replicability of the results. Further, in scientific debate, anyone is free to criticize the work of others. Provided a scientist's comments are cogent, arguments over credentials, (such as where the person went to graduate school), are of no great importance to the scientific debate. To be sure, scientists are not immune to someone else's prior work and scientific reputation and gradations among scientists do exist, (such as graduate student, junior and senior research staff), but a person's status does not preclude him from undertaking significant research or from criticizing the work of others. Many scientists do their most brilliant work early in their careers, yet the legal system often seems to militate against admitting or using younger scientists as expert witnesses.

Turning to our interest in the decision process, we pose the following two questions: (1) What changes could be made in the legal process to bring it more into accord with scientific traditions? and (2) Are such changes desirable? Several modifications to the present system appear readily available.

First, pre-trial discovery procedures could require that (a) at an early stage expert witnesses be allowed or even required to submit prepared testimony containing all major evidence they wish to cite and all important opinions they wish to express; 16/ (b) in general such prepared testimony should be in a publishable format, which means that it be reasonably self-contained, including complete citations to all references and that all charts, figures and tables be properly labelled and have proper titles, etc.; and (c) this prepared testimony in fact be published, with EPA acting as "the publisher of last resort." This procedure, in keeping with the spirit of pre-trial discovery procedures, would greatly reduce the role of initial direct examination of expert witnesses by the counsel who introduces the witness. The examination would be replaced by a carefully prepared written statement, which would be more in keeping with scientific tradition. Under this procedure, important professional opinions would not generally be introduced during subsequent oral presentation except, perhaps, if called for under cross-examination. This procedure will permit all expert opinions and professional judgments introduced as evidence to be circulated widely by both sides, with the purpose of subjecting a person's scientific views to intensive scrutiny by a wide range of interested scientists. The foreknowledge that the opposing side is likely to circulate and debate opinions more widely, in the scientific literature as well as before an administrative law judge, can only serve to enhance the quality of both the evidence and the debate.

A second possible change would be to permit any witness to challenge any opinion (or any other statement) expressed by an expert witness. The only requirement would be that any such challenger must also be subject to cross-examination and possible rebuttal. In other words, to challenge a statement by an expert witness, one would not have to qualify first as an expert witness. The court would, of course, be expected to consider any reasonable challenge or criticism on its merits. A procedural change of this nature, while possibly at variance with legal tradition, would appear to be in keeping with accepted scientific method. Such a change might, of course, be quite time-consuming if firms brought in many witnesses.

If the preceding change were adopted and led to frivolous and seemingly capricious challenges (this seems an unlikely prospect, but it cannot be discounted altogether), a third possibility would be to establish a new intermediate category of qualified witness, whose prerogatives would be to challenge opinions and raise pertinent questions, without being allowed to express unlimited opinions before the court.

A fourth alternative, for cases that focus on the accumulation and interpretation of scientific evidence related to future outcomes -- such as pesticide cases -- might be to relax substantially or even eliminate altogether the concept of expert witness. The idea is that the definition of an expert witness would have absolutely minimal qualifying hurdles, beyond which gradations in credentials and resumes would, *per se*, be of no particular importance. Then, hopefully, the focus of the testimony, cross-examination and debate would be on the substance and particulars of the issue. If this result were accomplished, adversary-type proceedings concerned with low-probabability, high-consequence matters might be conducted more in accord with "good" scientific method.

Scientific advisors to the court. As indicated previously, cases involving the cancellation or suspension of a pesticide's registration, such as the chlordane/heptachlor case, are conducted within an adversary legal framework. This framework seems particularly well suited for fact-finding and adjudication of a prior occurrence such as an alleged breach of contract. The central concern of a pesticide case, however, is the assessment of future risks and costs occasioned by pesticide residues against the future benefits that would result from continued use of the pesticide. Prior "facts" are relevant only to the extent that they help in this assessment. Thus, while the case represents a legal trial in one sense, in another sense it can be viewed as a process of information-gathering and scientific/technological assessment. This latter viewpoint deserves further discussion.

In pesticide cases, much of the information that is brought together (i.e., the evidence) will be of a technical nature; some of it may be highly technical. Although administrative law judges develop a certain amount of background and expertise in the area of their specialty, their primary training and professional experience is in the law, and they may at times experience difficulty in understanding and integrating large amounts of detailed and highly technical information. It might be a good idea, therefore, to enable a judge to appoint special scientific advisors to assist him in sifting and interpreting the evidence. 17/ Other public decision-makers, be they administrators in the executive branch or congressional committees, typically have unrestricted access to advisors and consultants.

When regulatory agencies were first established during the 1930's, the then-prevalent theory was that an administrative law judge could draw on members of the agency staff if he felt that he needed professional guidance or opinions. In light of current realities, however, this is totally infeasible. As Spector 18/ points out, EPA's Office of General Counsel treats the Office of Pesticide Products as if it were its "client". Consequently, the Office of Pesticide Products is cast in the role of the prime adversary party in challenging continued registration of the pesticide. Clearly, this aspect of the original theory underlying administrative law practices is no longer valid. It is against the rules of both common sense and the law for a judge to seek professional advice from one of the two opposing parties.

Scientific advisors to the court might play other useful roles as well. For instance, the classical adversary process depends entirely on the initiative of the opposing sides to determine who will be the witnesses, what will be submitted in evidence, and what questions will be asked of the various witnesses. Advocates clearly have strong incentives to put forth their best case, and the process has undisputed strength in bringing forth a considerable amount of pertinent evidence and viewpoints. When viewed as a social decision process, however, the system is by no means foolproof. The central issue in pesticide cases is posed with disarming simplicity. Because it is posed as a "yes/no" or "go/no go" decision -- i.e., continue or discontinue the pesticide's registration for a particular use or uses -- at first blush the issue appears to involve only two opposing sides, whose vested interests cover all important aspects of the issue. But broad social issues with widespread ramifications (and decisions concerning risky pesticides are included in this category) often have more than two major facets. This means that all important interests may not be represented during the hearings on a pesticide case. The possibility always exists that two opponents may reach an accommodation at the expense of a third party. At the same time, participation in any administrative law proceeding is time-consuming and expensive. The viewpoint most susceptible to being omitted is that of the general public. Consequently, when this occurs, the legal-adversary process may fail to ask questions that, from a broad social viewpoint, are highly pertinent. A question never asked will be a question never answered. However, if everyone attempts simultaneously to be a free-rider, none of the free-riders will be represented. Thus a second role for scientific advisors to the court would be to provide the judge with lists of additional evidence which should be requested and all pertinent questions that ought to be asked. Permitting scientific advisors to play this role would of course require a concomitant change in procedure to permit the judge to initiate requests for clarifying evidence and information. 19/

Publication of scientific evidence. This represents an expansion of the the idea broached earlier in the discussion on the role of expert witnesses. Openness of communication, including publication and peer review of all theories and significant experimental results is basic to the scientific method. The legal method is not altogether dissimilar. Legal tradition requires all formal proceedings to be carefully and scrupulously recorded and made part of the public record. Moreover, in preparing a case, lawyers and their witnesses can be expected to draw on all published material that is relevant and helpful to their position. Thus there is considerable harmony between the scientific and legal approaches.

Discordant notes arise from other parts of the system, however. Pesticide cases will inevitably involve a number of business firms: e.g., manufacturers, fabricators, wholesalers and distributors. With regard to openness of communication and sharing of knowledge, the business viewpoint stands at sharp variance with the scientific viewpoint. In a world of imperfect knowledge, business firms attempt to build up an internal base of research results, know-how and industrial secrets which they use to gain competitive advantage. One result of this internalization of information by business firms is that experimental data and findings introduced as evidence into pesticide cases will often not have been published in the scientific literature. For unpublished evidence it naturally follows that neither the experimental procedures nor the findings and interpretation of the data will have been subjected to the usual scientific peer review process (which includes possible attempts to replicate critical experiments). From the viewpoint of our study of the decision process, two pertinent questions are: (1) What changes, if any, can be made to the legal process to bring it more into accord with scientific traditions? and (2) Would such changes be desirable?

The volume of unpublished scientific evidence and data presented in a trial represents only a small fraction of the total trial record. However, such data can play a key role in the decision process. One possibility, therefore, would be to go beyond merely establishing a public record in a pesticide case, and instead (a) require that all expert witnesses submit unpublished data or evidence in a publishable form; and then (b) actually undertake to have all such evidence published, in as expeditious a manner as possible. That is, the author/witness might be allowed to submit and arrange for publication in a journal of his choice within, say, threee to six months, otherwise EPA would proceed with publication. Such a change in procedure would in no way diminish the value of a witness's evidence. To the extent that the expectation of publication causes witnesses to prepare their presentations more carefully and in more detail, such a change would seem to enhance both the scientific and legal value of the evidence. 20/ This change would be in keeping with the previously discussed possibility of improving pre-trial discovery procedures.

Conclusion

A number of different viewpoints -- e.g., legal, optimizing, scientific -- play important roles in the pesticide decision process. A full understanding of the total process requires an appreciation of all viewpoints. Because of the somewhat limited scope of this case study an in-depth exposition of the strengths, values, and weaknesses of each viewpoint is not possible. The discussion here has focused instead on certain critical differences between these viewpoints, the purpose being to sharpen the reader's awareness of the impact of each viewpoint on the total process.

It should also be pointed out that despite the differences discussed here, there is a single unifying theme. Namely, each of the different groups attempts to apply rational rules of reasoning to arrive at the "best" social solution. Each group is trained in and relies on its own methodology. While these may diverge at certain points, there are many key similarities.

Social choices concerning low-probability, high-consequence occurrences are often made in an atmosphere that is emotion laden and intensely personal for large numbers of people. Major vested interests, with huge investments in research, plant facilities and equipment may also be at stake. Social acceptance of the process by which choices are made is of utmost importance as we have seen from Part II of this study. Critical differences in cognitive methodologies tend to reduce acceptability of the process by influential groups, whereas similarities enhance acceptability. Therefore, the one recomendation that emerges from the discussion to this point is that more comparative study of the way cognitive methodologies relate to the decision process is needed.

This chapter concludes our review of the pesticide decision process as it now functions. The next and concluding chapter evaluates the pesticide decision process against the eight criteria developed in Part I of this study.

Notes to Chapter 9

1. A paradigm is said to be a mind-set underlying the interpretation of reality. It is more fundamental than a theory; it underlies particular theoretical approaches. It extends not only to the content of theoretical formulations built on it, but also to their form; to be in keeping with a paradigm, an approach must make use of a particular methodology, and must use particular instruments in particular ways. See Thomas Kuhn, The Structure of Scientific Revolutions, reprinted as a paperback from the International Encyclopedia of Unified Science 2nd Edition, enlarged, Vol. 2, (Chicago: University of Chicago Press, 1970).

2. The "political paradigm," consists of power, power blocs, conflicts in basic value judgments, conflicts of interest, methods for resolving conflicts, voting blocs, compromises, etc. The political paradigm is

especially applicable to the process which accompanies the enactment of all pesticide legislation. For one view of the political paradigm as it relates to the social decision process, see Ida R. Hoos, "The Assessment of Methodologies for Nuclear Waste Management" (mimeographed manuscript, undated), or "The Credibility Issue" (mimeographed manuscript, August 11, 1976).

3. For an elementary survey of decision theory, see A. N. Halter and G. W. Dean, Decisions Under Uncertainty (Dallas: South-Western Publishing Company, 1971).

4. U.S. Nuclear Regulatory Commission, Reactor Safety Study, An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants (October 1975) (NUREG 75/014 Wash-1400).

5. In its own way, the legal approach is also concerned with doing the best it can, in the light of the many realities mentioned here. Thus the legal outlook might also be dubbed an "optimization" approach, but it is optimization in the face of severe conflict and in light of broader considerations.

6. Many regulatory agencies, unlike EPA, are designed to be independent of the executive branch. In both theory and practice, agencies such as the ICC are less politically accountable than the Administrator of EPA, who serves at the pleasure of the President.

7. All too often cost-risk-benefit models fail to treat explicitly the range of uncertainty surrounding certain variables. Techniques do exist. Parametric analysis, showing how different values affect the final outcome, can be used. Rarely, if ever, does a cost-benefit model contain a variable indicating the extent of conflict involved in an issue.

8. For instance, many scientists are specialists trained to look at relatively narrow issues, and to think of optimization within narrow constraints. Others, such as systems analysts and ecologists, have a somewhat different mind-set because they are trained to think broadly about interdependencies and linkages of narrower subsystems.

9. See Notes 11 and 12, Chapter 6.

10. It is possible, at least conceptually, to consider all practitioners of cost-benefit analysis to be scientists, from one discipline or another. But all scientists are by no means "optimizers" or practitioners of cost-benefit analysis. The "scientific" paradigm thus differs from the "optimization" paradigm.

11. Spector, "Regulation of Pesticides. . .".

12. An important and much-discussed aspect of the legal process is its effect of deterring future actions deemed undesirable. But deterring future behavior by people and assessing the probability of future occurrences,

especially when all parties admit that the probabilities are "low", are not the same thing.

13. Non-lawyers sometimes express opinions to the effect that the law overemphasizes "procedure" at the expense of "the truth". A hypothetical example of such an instance would be the following situation. Suppose someone had stolen internal records from a business firm which indicated that over a long period of time a particular product would cause biologic malfunction of some kind. Suppose further that the only way this evidence can be replicated is by long, drawn-out controlled experiments. Evidence obtained by illegal means typically cannot be introduced into a formal trial. Some would feel, however, that rule of evidence is inappropriate in a legal proceeding aimed at preventing future occurrences, not at convicting someone for past events.

14. Thus to some scientists any decision process will appear to reflect an unscientific outlook.

15. See, for example, Arthur Kantrowitz, "Controlling Technology Democratically". American Scientist, September-October, 1975, pp. 505-509, and reference cited therein.

16. The procedure of requiring expert witnesses to submit written statements in advance is already used by some regulatory agencies, such as the Federal Communications Commission.

17. Rules and procedures governing the conduct of such scientific advisors would have to be developed. Ex parte communication is one potential problem. Perhaps all communication between the judge and any such advisor should either occur in the courtroom (before the opposing parties), or it should be in written form and made available to both opposing parties.

18. Spector, "Regulation of Pesticides. . .".

19. The idea of a science advisor to the court is the "inverse" of the Science Court concept, wherein scientists would play the role of judges, and judges of the Science Court would have legal advisors available to them.

20. In a formal suspension or cancellation proceeding, business firms are not required to submit in evidence proprietary information which supports their case. However, they typically find it in their best self-interest to do so. After business firms voluntarily enter information into a formal proceeding, it becomes part of the unpublished public record. Publication of such information is a relatively modest proposal. A major issue confronting EPA, and not touched on here, is how to reconcile the Freedom of Information Act with proprietary information submitted as part of the registration process.

10. Evaluation of the Pesticide Decision Process

This chapter aims to bring together the facts of the chlordane/heptachlor case study and the theoretical considerations presented in the preceding chapters to arrive at a tentative evaluation of the entire pesticide decision process.

In a broad perspective, it should be recognized that the cancellation and suspension proceedings for pesticides represent only one of many decision processes for making social choices under conditions of low probability, high consequence outcomes. When decisions must be made involving similar circumstances in other areas -- such as the supersonic transport, the siting of nuclear reactors, or disposal of nuclear wastes -- a process of gathering, presenting, disseminating and weighing scientific information is undertaken by the government. From one situation to another, the process may vary considerably. Congressional committees, for example, do not use a formal adversary proceeding; instead, they utilize what is referred to in legal parlance as an "inquisitorial" proceeding. 1/ That is, persons who testify before congressional committees are not cross-examined by opposing legal counsel, but are subject to interrogation by members of the committee. The process of determining who will testify before congressional committees differs from adversary proceedings and can, on occasion, be somewhat political.

The National Academy of Sciences, while not a formal decision making body, provides important input to the decision process by conducting investigations and issuing reports. Committees of the National Academy, like committees of Congress, use inquisitorial procedures for hearing witnesses and gathering information on a subject. However, committees of the National Academy do not typically hold public hearings, nor do they publish the testimony and proceedings that take place before their committees. Also, since committees of the National Academy are far less political than committees of Congress, the determination of whom to invite, or whom to permit to testify is subject to fewer political influences and considerations.

As was pointed out in the preceding chapter, the inquisitory procedures used by both the committees of Congress and the National Academy of Sciences are not the only institutional alternatives available. A number of interested and informed parties have advocated that a new type of adversary proceeding be established. The proposed institution is presently called, for want of a better name, the "Science Court". Advocates of this concept feel that serious shortcomings exist in our existing institutions for gathering and weighing scientific evidence on important issues of social choice. In general, the Science Court would complement, not replace existing decision processes.

The existence of such different ways for gathering, disseminating and weighing scientific information, coupled with the fact that new institutions and modifications of our existing institutions can be invented, focuses attention on the need for criteria to compare and evaluate our decision processes. Part I of the overall study has developed one such set of criteria. In this concluding chapter of Part II, the pesticide case study, we shall evaluate the decision process used in the chlordane/heptachlor suspension case by reference to the eight criteria specified in Chapter 4, Part I. For ease of reference, these criteria are listed in the accompanying Table 5.

1. Are parties who incur the present costs adequately represented? Parties presently at risk are all members of the general public who ingest the pesticide residues. Additional costs are born by anyone who has developed or will develop cancer as a result of ingesting pesticide residues. Those who develop cancer, together with their families and associates, bear all the human suffering which accompanies the disease. Some of the monetary burden, namely the cost of treatment covered by health insurance, is spread directly among the general public. However, since everybody is at risk, to quite a large degree it is the general public that is affected by the harmful residues. In the chlordane/heptachlor case the interest of the general public was represented by EPA from within the public sector and by the Environmental Defense Fund from the private sector. No health insurer joined the case to represent the public interest, and no other government agency joined the case on the side of the public. In other words, the Secretary of HEW, the Surgeon-General, the Director of the National Institute of Health, and the Director of the National Cancer Institute did not ask to join the case as interested parties or intervenors (however, professional staff from HEW did testify in support of EPA's position). Thus from within government, EPA alone represented the interest of the general public.

The adequacy of representation on behalf of the parties who bear the present costs depends on how well financed were those representing the general public. The Environmental Defense Fund was poorly financed, and this again raises the issue of whether some means should be instituted for at least partially compensating parties who successfully initiate or intervene on the side of those who bear the present (or future) costs. There is precedent for compensation within the legal process. In a class action brought by a few people (or even a single individual) on behalf of other members of an affected class, the attorneys representing the plaintiffs can expect to receive sizable fees if they are successful. Pesticide cancellation and suspension cases, however, have not yet been brought as class action suits because there are no specific damages or awards from which a fee could be paid.

To summarize, in this particular case we observe that once the proceeding was instituted by the Environmental Defense Fund, EPA clearly represented the public interest, and its side of the case appears to have been well financed, well prepared, and well presented. 3/

2. Are the parties who obtain the present benefits represented? Significantly, the Secretary of Agriculture filed to intervene in opposition to the suspension order, 4/ along with special interest groups that included the manufacturers, several dozen distributors of products containing chlordane

TABLE 5

Criteria for Evaluating Decision Processes Embodying Low Probability, High Consequence Risks[*]

1. Are parties who incur the present costs adequately represented?
2. Are the parties who obtain the present benefits represented?
3. Are interests of future generations suitably considered?
4. Are the distributional aspects considered systematically?
5. Are the social decision-makers unbiased and open?
6. Is the development of knowledge concerning the effect of possible alternative decisions adequate?
    a. Do views that appear to come from reasonable sources receive — or appear to receive — "equal time and treatment"?
    b. Are all significant differences considering the quality of knowledge included?
    c. Are the gaps in knowledge identified?
    d. Are procedures for collecting knowledge of the area efficient?
    e. Are the plausible consequences spelled out for the worst contingency?
    f. Are alternatives suitably considered?
7. Is information given to the individuals who are at risk?
8. Can a decision change if significant new information is obtained?

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[*] Source: Part I, Theoretical Considerations, Chapter 4, pp. 31-35.

or heptachlor, and farm groups whose members used chlordane and heptachlor. Thus all parties directly benefiting from the sale and use of the pesticide were strongly represented, as was to be expected.

3. Are interests of future generations suitably considered? Decisions concerning pesticides appear to involve the interests of future generations only marginally, because the persistence or effective half-life of pesticide residues is rarely over 3 - 5 years. For chlordane and heptachlor it was estimated that if all usage ceased, then within three years the amount of residue in foodstuffs would decline to an almost imperceptible trace. Follow-up studies on DDT have shown that the amount of residues in the environment declined fairly rapidly once usage was terminated. Thus persons affected by residues from pesticides applied this year will be the present generation plus, perhaps, children born during the next three or four years.

4. Are the distributional aspects considered systematically? Parties opposed to the suspension of chlordane made a major point over the potential impact on farmers who rely on chlordane/heptachlor products to control corn cutworm (the "horizontal equity issue" discussed in Chapter 8). The arguments were heavily weighed by the judge, who stated in his recommended decision that he "agonized over the impact which suspension would have."

Beyond the immediate impact on certain corn farmers, EPA introduced evidence to show that suspension would have relatively little effect on total output or the price of corn, since (a) chlordane products were used for insurance purposes on only 3% of the total corn crop, and (b) corn not pretreated with chlordane could be "scouted" at regular intervals after planting and then treated with other pesticides if cutworm attacks were discovered. Some corn is distributed to consumers through retail grocery outlets, and a reduction in output might have some small effect on the retail price of corn to consumers. Not all corn goes directly to consumers. A considerable amount of corn grown in the United States is used to feed cattle and poultry. The effect of a small reduction in output on the price of feed would be relatively slight since soybeans and other crops are also used for feed. Beyond the discussion about adjustments faced by corn farmers and price effects, there was little systematic consideration of distributional effects. Similar statements could be made about other crops for which chlordane or heptachlor is used to control some specific pest (e.g., Hawaiian pineapple). To the extent that price effects from suspension are in fact minimal, one might be excused from such a discussion on the ground that it is not particularly material to the proceeding. Even if the price effects had been significant, one is left with the uneasy feeling that nothing more would have been submitted as evidence about the incidence of price changes in different income groups within society.

The legal tradition is to worry about considerations of equity, but the formal cost-benefit model ignores distributional effects and equity considerations. This is an important difference between the legal and optimization paradigms. Except for studies on the regressivity of taxes, the tradition in many areas of economic analysis is to ignore distributional effects. In Chapter 8 we suggested that it might be helpful to require one or both of the two opposing sides to submit a formal cost-benefit analysis. Even if this were done, however, the distributional impacts of cancellation or suspension might not be subjected to systematic consideration.

To summarize, distributional effects were considered, but not in any systematic way. Moreover, even the most rigorous cost-benefit analysis will ignore distributional effects. Therefore, in order to assure that distributional impacts are systematically taken into account, it might be helpful to require both sides to submit a formal "distributional impact statement". This impact statement would complement a cost-benefit analysis by indicating how the estimated costs and benefits used in the analysis are distributed. Distributional impact statements are already routinely required, for example, in studies prepared for the Congressional Office of Technology Assessment.

5. Are the social decision-makers unbiased and open? In the chlordane/heptachlor case, and in any other pesticide case, the procedure is well established. First, the case is heard by an Administrative Law Judge, who holds an executive appointment and is usually a well-qualified professional whose sole duty is to preside over administrative law proceedings. To prevent judges from exercising open bias, strict rules exist regarding the disqualification of judges. Should a judge with a known vested interest not disqualify himself, the case can, on appeal, be overturned on this issue. There is thus good assurance that this level of decision-making is reasonably free of bias. However, although the Administrative Law Judge is doubtless quite influential in shaping and determining the ultimate result, he is not the final decision-maker. The Administrative Law Judge renders a lengthy, detailed opinion, containing both the recommended decision and the major facts and reasoning which underlie it.

The Administrative Law Judge's recommended decision is submitted to the Administrator of EPA, who has responsibility for rendering a "final" decision. To emphasize that it is the Administrator, and not the Administrative Law Judge who makes the final decision, we point out that in the chlordane/heptachlor case the Administrator did not accept the recommendation of the Administrative Law Judge (who recommended against suspension) and instead chose to suspend chlordane and heptachlor for most uses. The Administrator carefully documented his reasons for not accepting the Administrative Law Judge's recommendation.

The Administrator is a presidential appointee, like the heads of all other government agencies. The appointment of this key individual will, therefore, be subject to considerable political bargaining. Also, the Administratrator has numerous duties and responsibilities which extend far beyond presiding over adversary proceedings. Because of his continued contact with both environmental groups and industry, the Administrator will be subject to many pressures, but will also have as much information and perspective on environmental problems (especially policy issues) as anyone else in the country. For all these reasons, the Administrator can be expected to give a carefully reasoned and balanced, if certainly not disinterested, decision on all pesticide cases. This is probably the best that can be hoped for under the circumstances. The explicitly political nature -- and attendant public responsibility -- of the decision making process can be regarded as one of the strong points of the existing institutional structure.

Beyond the Administrator's decision, either party may appeal to the courts. Federal judges are less subject to short-term political influence than a political appointee in the executive branch of the government, but in the longer run the courts have been sensitive to the currents of public opinion. Federal judges will, however, be considerably less informed about environmental problems than EPA's Administrator. Thus, to the extent that pesticide cases are appealed to the federal courts, the decision makers will be freer of bias and more open. This multi-tier review process helps greatly to free the system of undue personal bias.

6. Is the development of knowledge concerning the effect of possible alternative decisions adequate?

a. Do views that appear to come from reasonable sources receive -- or appear to receive -- "equal time and treatment"? In the chlordane/heptachlor case a large number of firms and organizations asked to join the case in opposition to the proposed suspension order. The process is thus open, but this openness also has a potential for great proliferation and duplication of effort. Looking beyond the chlordane/heptachlor case, the more important point to emerge is that the legal process has the facility for consolidating large numbers of intervenors, and it can reasonably be expected to use this facility in a way that preserves openness while promoting efficiency.

b. Are all significant differences considering the quality of knowledge included? Cross-examination by knowledgeable persons is an effective and valuable means of bringing to light significant differences in the quality of information submitted as evidence. In regard to this particular criterion the adversary process appears to have advantages over, say, congressional hearings. It would appear, nevertheless, that the adversary process could be improved. In Chapter 9 we discussed the possibility of requiring that all scientific data and testimony be upgraded to a publishable level, and that such evidence in fact be published and made subject to more widespread peer review. This procedure would help bring out any significant differences in the quality of knowledge.

Improved pre-trial discovery procedures (e.g., requiring that expert witnesses submit prepared testimony containing professional opinions in advance of oral testimony) and the introduction of scientific advisors to the court might also improve the extent to which differences in the quality of knowledge are brought out.

c. Are the gaps in knowledge identified? The legal process used in pesticide cases can generally be counted on to produce a great deal of evidence. The chlordane/heptachlor suspension hearings were conducted under a "tight" time limit of 90 days (a subsequent 10-day extension was granted), yet the record contained over 10,000 pages of testimony and evidence. It would be naive to assume that a large bulk of evidence necessarily means that knowledge, and gaps in knowledge, are adequately revealed by the process. "Adequacy" is a relative term; the quality of evidence is what matters, not just the volume. How adequate knowledge is depends on what other knowledge could be made available during the decision process (i.e., at the time of the hearing) but is in fact not brought out.

This raises a further issue. The availability of knowledge could, at any time, be increased by defining and undertaking significant new research projects. Such a potential increase in knowledge would involve both large expenditures and time lags, and is not intended to be covered by the effort designed to bring out existing knowledge. Yet there exists no sharp dividing line between efforts aimed at "bringing out existing" knowledge and efforts aimed at "increasing" knowledge. Useful "existing" knowledge is often buried in a mountain of useless information from which it must be retrieved by large expenditures of time and effort. In this regard the bringing out of existing information for legal purposes is very much like the search for new knowledge. Conversely, new research projects are very much like information retrieval, especially in the area of social impacts, since they do not create information out of a void, but gather information that is in some way hidden or encoded within society or nature.

In the context of the adversary model used for suspension and cancellation hearings, we can examine the question from the two viewpoints of those opposed to and those favoring cancellation. One particular facet of adequacy is then the issue of how well financed each side is. Those opposed to cancellation will usually be well financed since this position represents concentrated interests, and in general they can be expected to submit in evidence most of the knowledge, experimental outcomes, or other arguments favoring their position. On the other side of the issue, the specter of the free-rider looms large. In other words, where many individuals benefit from an indivisible joint outcome that must be supported by their pooled voluntary contributions, each individual is motivated to take a free ride on the efforts of all the others, thereby undermining the viability of the enterprise. As noted in our earlier discussion of the first evaluation criterion, the legal process for pesticide decisions, per se, has no way of assuring any funding whatsoever for the public position. All funding comes from the political process that accompanies and underlies annual budgetary decisions.

In the chlordane/heptachlor case the EPA appears to have done a good job of collecting evidence and mobilizing highly knowledgeable witnesses, insofar as the effects of chlordane/heptachlor taken in isolation, are concerned. The availability of knowledge favoring cancellation arose largely from the government's monitoring effort and government sponsored research, and the mobilization of that knowledge on this issue was due mostly to the effort by EPA.

The most critical gap in knowledge -- never adequately brought out or emphasized by the decision process -- pertains to the possibly harmful synergistic effect of chlordane/heptachlor in interaction with other environmental or biological contaminants. When such synergistic effects are present, risks owing to individual agents are not simply additive, but can enhance each other manyfold. In areas of risk other than those involving pesticides, known harmful synergies occur, for example, between smoking and urban air pollution, smoking and the use of birth control pills, or the intake of barbituates and alcohol. The suspension hearings never brought out our profound ignorance concerning possible carcinogenic risks of chlordane/heptachlor residues in conjunction with smoking, with urban air pollution, with chemical food additives, with common drugs, or with other pesticide residues. Perhaps no such synergies exist. But if any deadly synergies should exist, the current decision process can certainly fail to take them into account.

d. Are procedures for collecting knowledge of the area efficient? The avoidance of serious overlap and duplication does not close the issue of efficiency. The proceedings of the chlordane/heptachlor suspension case generated a substantial amount of material, and the volume of information that will be generated during the full cancellation proceeding can be expected to dwarf that of the suspension hearings. The information which is submitted is carefully catalogued and accessible, in the best legal tradition. The question is: Could the bulk of the most important information be brought together in a more efficient way? In this regard, we have the feeling that there might be room for improvement. For example, the law stipulates that the Administrator must consider benefits -- i.e., cost-risk-benefit analysis is specified as the basic decision framework -- yet neither side in the suspension hearings actually prepared and submitted a cost-benefit analysis. Voluminous information on costs and benefits was submitted, in what might be described as piecemeal fashion, but there was no single vehicle for bringing together and consolidating all this information. No formal cost-benefit model was submitted in advance, although one most certainly could have been specified. Similarly, as we pointed out previously, there was no attempt at formal risk analysis. What might be helpful, therefore, would be to require one or both parties to submit a formal cost-benefit analysis, complete with estimates of all future benefits and costs, discount factors, breakeven analysis, etc., in much the same way that environmental impact statements are now required in many areas. The extent to which both sides either agreed or differed with the analysis contained in a formal model might be of great help in narrowing and focusing the issues. Formal specification of risk-benefit models, especially if done within the adversary setting, might in time also help broaden public familiarity with and acceptance of the optimization paradigm.

Another issue relating to the identification of gaps in knowledge concerns whether a sufficient number of the "right" questions were raised during the hearing. As the discussion about possible science advisors to the court pointed out, the existing adversary process relies almost totally on opposing counsel to ask the right questions, but in highly technical matters this approach may be deficient. Given the preponderance of lawyers present at such hearings, there is good assurance that all pertinent legal questions will be raised. However, counsel for both sides may fail to ask some highly relevant scientific questions, particularly when the questions and issues are of a technical nature. Scientific advisors to the court, coupled with the ability of the judge to ask questions pertaining to issues not adequately covered or not otherwise raised, would provide additional assurance that adequate knowledge will be divulged by the process.

To summarize, the knowledge brought out in the chlordane/heptachlor case appears to have been generally adequate, but this may have been an exceptional situation. It resulted from the adequate financing provided by EPA, and the cooperation of several witnesses from other government agencies. When affected parties on one side of an issue are virtually all free-riders, then the legal process -- as presently constituted -- has few built in assurances that adequate knowledge will be forthcoming.

e. Are the plausible consequences spelled out for the worst contingency? In the chlordane/heptachlor suspension hearing the plausible consequences were not clearly spelled out for the worst contingency. As noted previously, one witness stated that a probability of 10^{-4} in a population of 2×10^{8} would result in 20,000 deaths, but that was not put forth as either his best estimate of the risk or as the worst contingency.

As with all low-probability, high-consequence outcomes, there are a great many unknowns concerning the risks associated with pesticide residues. It is not known, for instance, whether chlordane/heptachlor residues are more likely to induce some types of cancer more than other types; nor do we know how many years of continued exposure will, on the average, result in a known number of cases. As indicated before, we know nothing about synergistic effects. Still, it would seem helpful to have some concept of the worst possible consequences spelled out. In some instances the spelling out of the worst possible consequences (to be compared with the potential benefits from continued usage) might be more helpful to those advocating registration, and in other instances it might be more helpful to those advocating suspension and cancellation. We do not know which side would have been helped in the chlordane/heptachlor case, and this discussion is not intended to fault either side in the preparation and presentation of its case. If there is any failing, it is that the process itself does not require this type of information to be prepared and submitted.

f. Are alternatives suitably considered? Does the process explicitly recognize the uncertainty and lack of knowledge about pertinent alternatives or possibilities? In a pesticide suspension or cancellation proceeding, such as the chlordane/heptachlor case, the range of alternatives considered is narrow. The principal alternatives to non-use of the pesticide at issue currently are:

- The use of other pesticides or other pest control techniques against those pests which are known to be controlled by the pesticide whose registration is being challenged.

- Growing other crops which are not susceptible to the pest controlled by the pesticide whose registration is being challenged.

As indicated in Chapter 7, one of the principal agricultural uses of chlordane, especially in low-lying areas with poor drainage, is to control the corn cutworm, which has a devastating effect on a corn field if uncontrolled. The alternatives are to use other means of controlling the corn cutworm, or to grow some other crop that will not be affected by the corn cutworm, such as soybeans. During the chlordane/heptachlor suspension case extensive evidence was presented on both alternatives. However, both the recommended decision by the Administrative Law Judge and the final decision by the Administrator focused their attention almost exclusively on other means that are available to control the cutworm (and that would permit those farmers using chlordane/heptachlor to continue growing corn), and gave scant attention to the possibility of growing other remunerative crops on the same land. On the basis of this one case study, we do not know whether this result is a peculiarity of the chlordane/heptachlor case, or whether there is a subtle bias in the law which gives heavy weight to those alternatives which would preserve both the "physical substance" as well as the economic substance of a farmer's situation. If such a bias exists, then it might be useful: (a) to have it brought out into the open and discussed; and (b) to develop formal checklists or models for use in such cases to help prevent important factors (such as good economic alternatives) from being systematically omitted. In light of the extensive evidence which the judge must sift in such cases, it is entirely understandable that something like alternative uses of the land might escape attention in the final decision. However, such a relatively narrow focus may also be the result of a systematic bias.

As regards the particular alternatives discussed above, the adversary system is capable of developing the necessary detail and bringing many to the attention of the decision makers. This was in fact done in the chlordane/heptachlor case. There are instances of broader policy alternatives available to society but they fall outside the scope of the legal process specified in the applicable legislation. Such alternatives will therefore be irrelevant and immaterial to the legal proceeding. The application of chlordane to control the corn cutworm provides a good example of the possibility of applying broader policy alternatives. Corn growers apply chlordane in the early spring, before the crop is planted, and before it is known whether cutworms will be a problem that year. In other words, chlordane is applied as "insurance" against cutworm infestation. As occurs with all "insurance" policies for casualty-type events, only some will (or would) suffer from the casualty event which is being insured against. Just as most home-owners who buy insurance will not suffer from fires, so most corn farmers who use chlordane would not actually suffer from cutworm infestation. The fact that the use of chlordane is for insurance purposes, and not to control a known infestation, gives rise to a broader social alternative. Namely, create and sell to corn farmers an actual insurance policy that would cover cutworm infestation. It is entirely possible that the cost of such insurance would not be disproportionately greater than the cost of buying and applying chlordane, and it could well turn out to be quite a bit less. This would depend upon the extent of damage that would actually be done by cutworms (assuming that no chlordane were used). If the cost turned out to be lower, the advantage is obvious; if higher, some extra cost could still be advantageous from the social point of view in order to reduce the environmental impact of chlordane. 5/ However, as indicated above, any consideration of such alternatives is now beyond the purview of an administrative law proceeding.

The narrow conception of alternatives under the current decision-making process makes it all but impossible for some of the key dynamic effects of pesticide decisions to be raised in a legal proceeding in a relevant and material manner. These dynamic effects, discussed earlier, include: (1) effects of research and development aimed at new pesticides; (2) effects on the entry of new firms into the industry; (3) effects on research and development aimed at new non-pesticide pest control alternatives; and (4) effects on social adjustments modifying the entire interface between food production, resource use, and the total ecology. Raising issues connected with each of these effects implies consideration of the use or non-use of a given pesticide in the context of an extremely broad range of social alternatives. Moreover, the effects in question cannot be properly tied down to a decision concerning any single pesticide. They hinge much more on the entire economic and social climate created by a series of legally independent but substantially interrelated pesticide decisions. The current decision-making process effectively excludes such issues from consideration, yet over a horizon of just a few years these issues may have far more social importance than those laboriously considered.

7. Is information given to the individuals who are at risk? The legal process followed in pesticide cancellation and suspension proceedings establishes an extensive public record, which means that information brought out by the process is in principle available to individuals who are at risk. Yet this record is not published and circulated in printed form like the record of congressional hearings. To the extent that individuals at risk are represented at the hearings, as by the Environmental Defense Fund, they may receive information brought out during the hearings through publications issued by such organizations. Also, while the trial process itself typically receives little publicity, the final decision rendered by the Administrator tends to be "news", and this causes it to be picked up and disseminated by the general news media. Thus the process would appear to conform reasonably well to this criterion.

8. Can a decision change if significant new information is obtained? The registration of a previously registered pesticide can clearly be cancelled. Under EPA rules and regulations the process for reconsidering and reinstating the registration of a pesticide is generally similar to that for initial registration. Namely, a manufacturer, potential user, or other interested party (e.g., the Department of Agriculture) initiates the process by petitioning the Administrator for reconsideration. The basis for such reconsideration would be substantial new evidence as to the benefits or risks of the pesticide. Such evidence would be submitted with the petition, and reviewed by EPA. If the Administrator should decide that reconsideration is warranted, a full administrative law proceeding, open to the public, is then undertaken. This hearing can be as extensive as a full cancellation proceeding. Following the hearing the Administrative Law Judge submits a recommended decision to the Administrator, who issues a final order. Decisions of the Administrator can be appealed to the Federal District Court.

Summary and Conclusion

This case study has focused on the process by which social choices are made for one specific type of low-probability, high-consequence risk. The study has dealt with the decision to continue or suspend the registration of a pesticide whose residues are known to enter the human biomass and perhaps, as shown by limited evidence, exert carcinogenic effects. Specifics of the chlordane/heptachlor suspension case have been used as a means of gaining insight into the decision process and generalizing about it. At the same time we have discussed the decision process from a broader social point of view in order to put the EPA suspension-cancellation process into better perspective. The efficacy of a social decision process cannot be measured on an absolute scale; it must, rather, be judged in relation to other decision processes that are available to us.

Cost-risk-benefit analysis, as used in the chlordane/heptachlor case, was described and appraised in Chapter 8. In Chapter 9 the label "optimization paradigm" was applied to the principle underlying the cost-benefit approach, and it was contrasted to the "legal paradigm", which constitutes the basic framework of the current decision process. Both approaches were seen to have shortcomings.

The optimization approach attempts to determine the nominally best social choice for a given set of facts and circumstances. It has not, however, gone through the long and careful development of the legal approach. Its methods tend to be ad hoc rather than standardized; it is subject to few agreed-upon procedures or rules; its assumptions and the limits it places upon the scope of its models often seem arbitrary; and its conclusions are frequently colored by the personal biases of the individuals using the tools and techniques. For these reasons the optimization approach has limited acceptance or authority in social decisions.

The legal approach has deep roots in the lengthy development of civil and criminal law. The primary purpose of the legal process is to resolve conflicts according to the principle of justice under the law, not to seek some kind of "optimum" or "best" social decision. Accordingly, the legal process was developed to adjudicate and settle issues relating to events that have already taken place. It seems fair to say that the legal process was never intended to create a forum for gathering and weighing scientific information related to future outcomes, especially when those future events are subject to a high degree of uncertainty. Thus Congress has now mandated the generalization of the legal-adversary model to a situation for which it was neither designed nor intended. A major strength of the adversary model, however, is that the legal process enjoys broad social acceptance, regardless of whether it arrives at a "correct" or "optimal" decision in every instance. Since Congress has had no ready alternatives at its disposal, this broad acceptance is doubtless a major reason why it opted for the legal process.

In this chapter we have evaluated the current decision process -- which represents a marriage of the optimization and the legal paradigms in their existing mode -- against the eight criteria developed in Part I of the study. Generally speaking, as evidenced by the chlordane/heptachlor suspension case, the current decision process is seen to create a reasonable and acceptable way of dealing with the cancellation or suspension of individual pesticides, taken one by one, and considered against a narrow range of alternatives.

The current procedure can, however, offer no assurance against harmful synergistic effects of environmental contaminants in combination, nor can it guarantee that its outcomes will be reasonable and acceptable when considered against a full range of social options.

EPA is at the leading edge of societal change. It is inevitable that many issues which EPA must face will involve low-probability, high-consequence occurrences. Thus EPA is now and will continue to be the forum for resolving issues involving major areas of scientific and technical uncertainty, coupled with deep-seated conflict. Processes for dealing with this type of issue are the suject of concern and study by government agencies other than EPA. As these issues become of increasing concern to an ever growing segment of the population, social acceptability of the decision process is of paramount importance.

This study points to three recommendations. First, EPA should expand its research dealing with the decision process itself, particularly in the areas of synergistic effects and broad social options where the decision process is now weakest. Second, EPA should monitor, on a continuing basis, modifications and improvements in the process which may evolve elsewhere: in the federal government, in other public or private decision making bodies of this country, and in decision making agencies or overseas organizations that are working under a broad range of social and economic conditions. Third, EPA should establish a capability for continuous self-evaluation of its major programs that embody decision processes, focusing on its own success so far as compared with other major U.S. regulatory agencies, in maintaining a posture of independence in relation to the key interest groups subject to its regulatory action.

Notes to Chapter 10

1. The term "inquisitorial" is not used in any derogatory or pejorative sense. It is merely a means of distinguishing one type of hearing from an adversary-type hearing.

2. The risks and costs may sometimes be localized, as with the PCB incident in Michigan. But in view of the widespread network through which most crops are distributed, the situation represented by the chlordane/heptachlor case would appear to be more typical.

3. One should nevertheless be careful not to extrapolate too far beyond one case. In the past, political forces have managed to keep consumer agencies chronically underfunded. Also, among the ranks of regulatory agencies, EPA is still quite young. Many regulatory agencies, as they mature, come increasingly under the influence of the industries they have been created to regulate. Such influence is acquired when the regulated industry retains, at fees substantially higher than those paid by government, lawyers, economists, engineers and scientists who appear to be most knowledgeable and capable in the areas of regulation concerned. The "public interest" provides few jobs in the environmental area at places like the Environmental Defense Fund and Natural Resources Defense Council — and at comparatively low salaries. The EPA, of course, regulates many more industries than most regulatory agencies, and it may therefore resist capture by the affected interests longer and more successfully than other regulatory agencies . While EPA did a creditable job in this case, it is too early to advocate that EPA be the first and last line of public defense in environmental matters.

4. The Department of Agriculture intervened because it has used chlordane/heptachlor products in some of its quarantine programs.

5. Secretary of Agriculture Robert Bergland is reported to favor such an approach. According to the New York Times, Secretary Bergland plans to develop an "all-risk, all crops" insurance program to protect producers against disasters of the kind that had occurred in many parts of the country in the past year. According to Secretary Bergland:

> "The disaster provisions of our present laws are in and of themselves a disaster. . .
>
> "The Secretary said that he had been advised by private insurance companies that the risks of insuring crops were beyond their financial resources and, therefore, coverage was a federal responsibility."
>
> (New York Times, February 1, 1977, p. 17).

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Part III

CASE STUDY OF NUCLEAR WASTE DISPOSAL

11. Introduction

A degree of consensus exists among experts as well as the general public that the rate of adaptation of new technologies and their use in human endeavors have increased during recent times. 1/ There also appears to be an increase in public awareness of the presence of societal risks resulting from man-made activities 2/ as well as those derived from natural phenomena. 3/

This is a case study of societal risk management as practiced for nuclear waste disposal. Seldom has an issue associated with technological risk and uncertainty been more widely debated by the public than the subject of nuclear waste disposal. Further, both the public and the scientific community have generally assumed that risks associated with radioactive waste disposal can either be readily overcome by existing technologies or that catastrophy to mankind is inevitable. These radically different views are held not only by the general public but also by nuclear scientists, engineers, economists, and elected officials. The concern and differences of opinion on risks associated with nuclear wastes are significant and well informed.

The Catastrophic View

The Committee of the Pugwash Conferences on Science and World Affairs gave the following evaluation of man's current ability to store high-level wastes in perpetuity:

> No general solution for the isolation of long-lived radioactive wastes from the biosphere, for the necessary many thousands of years, is yet in hand; that is, despite a wide variety of proposals, 'experts' still disagree on whether any of them will suffice. . . It is impossible to be complacent about expansion in the use of nuclear power without having a solution in hand. 4/

A similar conclusion was reached by the Union of Concerned Scientists:

> The matter of man-made vaults at or near the surface for long term storage (500 years) is. . .uncertain. Their maintenance depends upon the existence of social and political institutions, the permanence of which cannot be guaranteed over time.
>
> The impression is inescapable, in view of the present imprecise state of affairs, that no convincing statements exist regarding the long term environmental impact attend-

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> ing the storage and/or disposal of wastes from fuel reprocessing. It is disturbing in this regard that the pace of development of a suitable waste disposal technology does not seem commensurate with the rate of expansion of the nuclear power industry. . . Fission technology requires that man issue guarantees on events far into the future, and it is not clear in most cases how this can be done. Institutional arrangements do not exist and never have existed to guarantee the monitoring of or attendance upon storage facilities over a millennium. In the range of a million years, serious geological uncertainties arise and even the survival of man may be doubtful. 5/

Distinguished scientists have also been outspoken to the effect that there is no assured means currently available to store high-level wastes "permanently." For instance, Hannes Alfven, 1970 Nobel laureate in physics, made the following statement:

> At present there does not seem to be any existing, realistic project on how to deposit radioactive waste; but there are a multitude of optimistic speculations on how to do so. The problem is how to keep radioactive waste in storage until it decays after hundreds or thousands of years. The deposit must be absolutely reliable as the quantities of poison are tremendous. It is very difficult to satisfy these requirements for the simple reason that we have had no practical experience with such a long term project. Moreover, permanently guarded storage requires a society with unprecedented stability. ....(T)he production of nuclear energy is necessarily associated with the production of radioactive elements; and a very large production of nuclear energy necessarily means the mass production of radioactive poisons in quantities which are terrifying.
>
> This is the basic reason for the opposition against the use of atomic energy, which has become a worldwide controversy. 6/

These radioactive wastes remain toxic for a very long period of time -- in some cases for hundreds of thousands of years. This means that they must never be permitted to escape containment. As pointed out by J. O. Blomeke et al. in a 1973 article, an inescapable commitment of the use of fission reactors for power generation is the management of radioactive wastes wherever they are placed. The management of nuclear wastes (from all types of fission reactors) requires isolation and/or containment until the wastes, through radioactive decay, become relatively stable and less hazardous. The time required for this is many thousands of years. Thus, the safety of waste management concepts must be evaluated in a geological time frame. 7/

According to current projections, several hundred billion curies of high-level radioactive wastes will have accumulated by the beginning of the next century. These wastes will contain over 1000 metric tons of actinides, the highly toxic, long-lived radionuclides that pose the bulk of hazards after several hundred years of storage. By the year 2000, 50,000 trillion cubic meters of water would be required to dilute the high-level radioactivity within standards set by the Radiation Concentration Guides. Some respected nuclear scientists are concerned over the ultimate disposal of these wastes. A. S. Kubo and D. J. Rose state:

> "The use of mausolea. . .is a temporizing measure. All countries currently using this concept intend to use some other method of disposal when new technology is developed or the wastes are more manageable." 8/
>
> "Storage in man-made vaults is generally considered to be useful only for interim storage since surveillance and controls are required." 9/

A summary of the concerns regarding nuclear waste risks was recently stated by Philip Micklin.

> A key unsolved problem of the nuclear age is the centuries-long management of extremely hazardous high-level radioactive wastes produced in reactors. Until recently, storage of liquids in underground high integrity tanks has been the prevalent repository mode for such materials. Tanks at Hanford and Savannah River have leaked wastes into the environment and the AEC* admits this is not a viable long-term management mode. . .
>
> In spite of unsolved problems, the AEC is convinced that long-term management of highly radioactive wastes poses no environmental hazards. They contend they, or some successor organization, will be able to provide the careful control of these materials required into the distant future or until a reliable permanent disposal system is found. On this assumption, no threat is admitted in the expected rapid build-up of wastes from power reactors over the next several decades.
>
> The AEC may be right. But if wrong, the consequences, borne primarily by future generations, will be catastrophic. As management and engineering systems are devised by humans, no matter how carefully designed they are inherently subject to failure, particularly over the long term. Hence, it may be prudent to consider stopping or at least slowing the headlong expansion of nuclear power and devoting our attention to developing less hazardous alternative energy sources until

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*Atomic Energy Commission

> more complete answers are provided to this as well as other problems of nuclear technology. 10/

Micklin's plea for more complete answers may be difficult to satisfy, if it is indeed true that these problems are beyond analysis (at least conventional risk analysis). These views have also been expressed by Alvin M. Weinberg, former Director of the AEC's Oak Ridge National Laboratory. He identified the question of whether to generate the highly toxic, long-lived wastes as "trans-scientific", a ". . .question which can be adjudicated by a legal or political process, rather than by scientific exchange among peers." 11/ Weinberg further stated:

> We nuclear people have made a Faustian bargain with society. On the one hand, we offer -- in the catalytic nuclear burner -- an inexhaustible source of energy. . . But the price that we demand of society for this magical energy source is both a vigilance and a longevity of our social institutions that we are quite unaccustomed to. . . The society must then make the choice, and this is a choice that we nuclear people cannot dictate. We can only participate in making it. Is mankind prepared to exert the eternal vigilance needed to ensure proper and safe operation of its nuclear energy system? 12/

Allen Kneese addressed the problem from an economist's perspective:

> It is my belief that benefit-cost analysis cannot answer the most important policy questions associated with the desirability of developing a large-scale, fission-based economy. To expect it to do so is to ask it to bear a burden it cannot sustain. This is because these questions are of a deep ethical character. Benefit-cost analysis certainly cannot solve such questions and may well obscure them. 13/

Actual past experience in waste management compared to future plans and proposals does not in general indicate that appropriate nuclear management techniques have been developed or are being used. On the contrary, past appraisals of waste management methods, conducted by the General Accounting Office (GAO), suggest that serious management and/or technical problems exist.

In this regard, information from two GAO reports should be noted:

> At the time of our review, Richland was faced with a potentially serious situation with respect to the condition of its existing tanks. The operating contractor has estimated that the expected life of the 20 Richland tanks equipped to accommodate self-boiling wastes is probably no more than 20 years or could be as little as 10 to 15 years. Eleven of the 20 tanks have been in service for 10 years or more. Further, recent studies have cast doubt upon the wisdom of reusing such tanks

> after they have been emptied, regardless of their age. In this regard, it appears that in the last half of 1969, Richland may be confronted with a situation of having only used tanks available as spare tanks for high-level self-boiling waste storage; . . .
>
> AEC informed us that the Lyons location probably could be used for long-term storage of AEC's high-level radioactive wastes; however, because of the estimated high cost (preliminary estimates are in the range of $1.5 to 2 billion) of processing, packaging, and shipping the wastes from Richland and Savannah River to Lyons, efforts are under way to determine whether suitable long-term-storage locations and methods can be developed at the two AEC sites. AEC believes that the cost of exploring and developing a long-term-storage method at these sites is justified, because of the potential expense of shipping the large quantities of waste at these sites to another location. AEC advised us that it probably would not be economically attractive for a commercial plant to make similar studies for its own location. 14/

Scientists' concerns with nuclear waste have been cited in some length because of the grave risks involved.

The Complacent View

Not all scientists have the same perception of nuclear waste disposal problems. David Rose summarized problems related to nuclear waste management this way:

> I think that the nuclear waste problem can be solved relatively cheaply; it has appeared as a problem mainly because the former AEC tried to force the problem into a box that was financially too small; anybody who would speak up against the policy would best find employment elsewhere. I have some personal experience with this particular matter. That was unfortunate, because the problem is relatively resolvable, at not too high a cost; there is a lot of option space yet to be explored. 15/

Similar views are held by many other distinguished scientists.

Overview of the Study

These quotations, representing groups of opinions, indicate the extent of polarization and conflicting opinions with regard to the societal risks related to nuclear waste management. They also indicate the applicability of nuclear waste disposal as a case study for social decision-making under conditions of low risk, high consequence outcomes.

Chapter 12 presents a brief technical description of nuclear waste generated within the nuclear power cycle, and describes all major nuclear waste disposal concepts and options. This provides a technical basis for discussing societal risk related to nuclear waste management.

Chapter 13 discusses the risk issues associated with disposal of nuclear wastes, and presents the more important unique physical features of nuclear waste that affect risk issues. The basis for subsequent discussion of risk analysis is derived from this information.

Chapter 14 gives the current legal framework for nuclear waste management and current federal radiation protection criteria. These form the legal and institutional basis for management of nuclear waste.

Chapter 15 contains a brief analysis of publicly voiced criteria for nuclear waste disposal. These criteria are extremely important in assessing strategies of nuclear waste disposal. They are uniquely important because they tend to represent societal views of health related issues, both present and future. The public participates in nuclear waste management decisions via provisions embodied in the National Environmental Policy Act (NEPA). Thus, understanding public concerns has become a critical prerequisite in analyzing nuclear waste management.

Chapter 16 starts with a discussion of benefit-risk-cost analysis as it applies to nuclear waste disposal. This chapter then uses the criteria developed in Part I of this study to evaluate the social decision process as it functions with respect to management of nuclear wastes.

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12. Disposal Concepts For Nuclear Wastes

This Chapter describes pertinent technical issues related to generation and disposal of nuclear waste.

Generation of Wastes

Radioactive wastes generated by the nuclear fuel cycle can be generalized into three categories: (1) high-level; (2) transuranium contaminated; and (3) low-level. 1/

High-level wastes are generated from reprocessing highly irradiated nuclear fuels. These wastes are so high in radioactive content of long-lived isotopes that they require long-term storage in isolation with essentially perpetual surveillance at storage sites. Before permanent storage can occur, these wastes must be processed into inert, immobile, solid material which is nonexplosive, noncombustible, and cannot turn to gaseous form and become airborne.

Transuranium-contaminated (TRU) wastes usually contain solid materials contaminated with significant amounts of long-lived alpha emitters such as plutonium.

Low-level wastes contain sufficiently low radioactivity that they do not present significant environmental hazards. Other risks are implicit in radioactive waste, however, regardless of the low level of contamination.

Although transuranium and low-level wastes present some initial risks, it is high-level wastes that are of critical concern. The first high-level waste was produced in the mid-1940's as a result of Manhattan Project activities. Since then, such waste arising from defense production and nuclear power development has been stored either as aqueous solutions or solids at various installations. Waste has been stored as aqueous solutions at the only operational commercial fuel reprocessing plant (West Valley, New York).

Exponential growth of nuclear power in the United States will result in increased quantities of high-level waste. The anticipated accumulation of solidified high-level waste before the year 2000 is about 13,000 cubic meters. Approximately 150,000 megacuries of radioactivity and 700 megawatts of heat will be associated with this projected waste inventory in the year 2000. 2/ Figure 2 shows most of the potential routings of nuclear waste, starting with its presence in the discharge reactor fuel and continuing to its final disposal.

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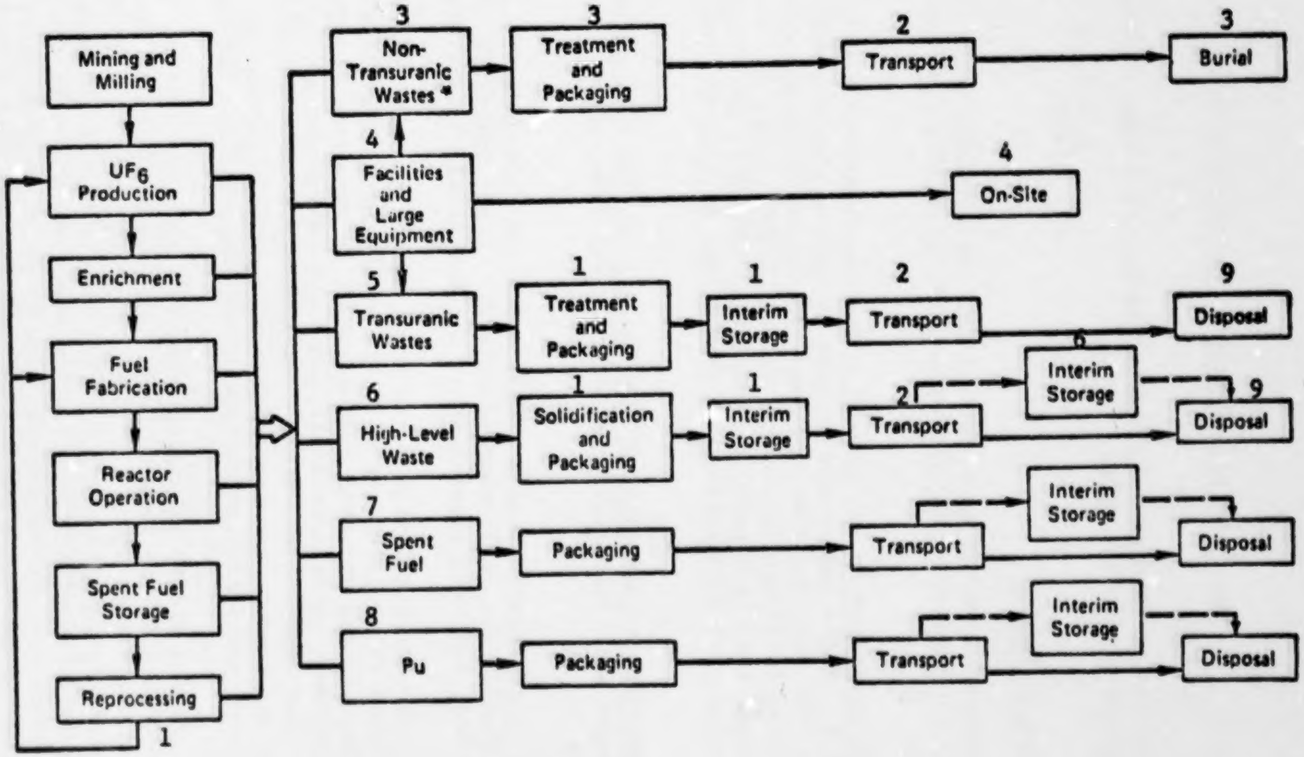
FIGURE 2

Generation of Nuclear Waste Within Nuclear Fuel Cycle:
Major Options for Waste Management


Mining and Milling
UF$_6$ Production
Enrichment
Fuel Fabrication
Reactor Operation
Spent Fuel Storage
Reprocessing
1
3
Non-Transuranic Wastes *
4
Facilities and Large Equipment
5
Transuranic Wastes
6
High-Level Waste
7
Spent Fuel
8
Pu
3
Treatment and Packaging
1
Treatment and Packaging
1
Solidification and Packaging
Packaging
Packaging
1
Interim Storage
1
Interim Storage
2
Transport
4
On-Site
2
Transport
2
Transport
Transport
Transport
6
Interim Storage
Interim Storage
Interim Storage
3
Burial
9
Disposal
9
Disposal
Disposal
Disposal

* Low-Level Wastes

The term "disposal" refers to placing the waste in permanent isolation, sometimes supplemented by man-made barriers to provide adequate protection, for a sufficiently long period for waste to decay to harmless radioactivity levels. Short-lived waste fractions will decay and become nonradioactive in relatively short times -- that is, times sufficiently short to consider long-term storage in man-made structures.

Partitioning (removal of actinides), fractionation (removal of certain fission products), fixation or conversion to encapsulated solids, and retrievable storage are identified as processing steps of the waste management method. Partitioning treatment of the waste is a key element in certain waste management systems. Dividing the high-level waste into long- and short-lived fractions allows the two waste fractions to be managed separately. The short-lived fraction will diminish to low levels in about a hundred years.

To produce a short-lived waste fraction which would decay to negligible radioactivity in about 1000 years requires separation of the actinide elements and perhaps samarium, technetium, tin, iodine, and nickel (radioactive nickel is due to irradiation and dissolution of some fuel cladding). Large decontamination factors -- the ratio of initial concentration in waste to final concentration in waste -- in a range 10^6 to 10^8 would be required for some elements, particularly actinides, to render the remaining waste materials non-radioactive after 1000 years of decay time.

In a broad sense, only three management options exist for the longer-lived and highly toxic actinide fraction of the waste:

(1) elimination of waste constituents by beneficial transmutation, which is nuclear conversion to other less dangerous isotopes;

(2) safe extraterrestrial transport off the earth;

(3) isolation from man's environment somewhere on earth for long periods to allow natural radioactive decay.

However, as discussed in more detail in this Chapter, transmutation and extraterrestrial transport cannot be implemented at this time. Therefore, only isolation is currently a viable alternative.

Characteristics of High-Level Waste

Table 6 shows typical constituents of the liquid high-level waste expected from the solvent extraction reprocessing of irradiated fuels from Light Water Reactors (LWR), Liquid Metal Fast Breeder Reactors (LMFBR), and High Temperature Gas-Cooled Reactors (HTGR). 3/ This waste is a nitric acid solution of chemical salts which typically contains a few volume percent of solids. The waste constituents include: nonradioactive chemicals added during reprocessing; almost all radioactive and nonradioactive fission products; transuranium actinides formed in the reactor; and about 0.5 percent of the fuel materials such as uranium, plutonium and thorium which are not recovered

TABLE 6

Typical Materials in High-Level Liquid Waste

		Grams/MT from Reactor Type[a/]		
	Material[b/]	LWR[c/]	HTGR[d/]	LMFBR[e/]
Reprocessing Chemicals	Hydrogen	400	3,800	1,300
	Iron	1,100	1,500	26,200
	Nickel	100	400	3,300
	Chromium	200	300	6,900
	Silicon	---	200	---
	Lithium	---	200	---
	Boron	---	1,000	---
	Molybdenum	---	40	---
	Aluminum	---	6,400	---
	Copper	---	40	---
	Borate	---	---	98,000
	Nitrate	65,800	435,000	244,000
	Phosphate	900	---	---
	Sulfate	---	1,100	---
	Fluoride	---	1,900	---
	Sub Total	68,500	452,000	380,000
Fuel Product Losses[f/], [g/]	Uranium	4,800	250	4,300
	Thorium	---	4,200	---
	Plutonium	40	1,000	500
	Sub Total	4,840	5,450	4,800
Transuranic Elements[g/]	Neptunium	480	1,400	260
	Americium	140	30	1,250
	Curium	40	10	50
	Sub Total	660	1,440	1,560
Other Actinides[g/]		<0.001	20	<0.001
Total Fission Products[h/]		28,800	79,400	33,000
	TOTAL	103,000	538,000	419,000

---

a/ Water content is not shown; all quantities are rounded.

b/ Most constituents are present in soluble, ionic form.

c/ U-235 enriched PWR, using 378 liters aq. waste/metric ton, 33,000 MWd/MT exposure. (megawatt-days per metric ton of fuel)

d/ Combined waste from separate reprocessing of "fresh" fuel and fertile particles, using 3,785 liters of aqueous waste per metric ton, 94,200 MWd/MT exposure.

e/ Mixed core and blanket, with boron as soluble poison, 10% of cladding dissolved, 1,249 liters per metric ton, 37,100 MWd/MT avg. expos.

f/ 0.5% product loss to waste.

g/ At time of reprocessing.

h/ Volatile fission products (tritium, noble gases, iodine & bromine) excluded.

during reprocessing. Most chemical materials are added during fuel reprocessing. 4/

Present regulations 5/ require that liquid high-level waste from fuel reprocessing (1) be converted to a solid material within 5 years after separation in the fuel reprocessing step, and (2) be encapsulated and shipped to a Federal repository within 10 years of its production for long-term management. Solidified high-level waste is assumed to be encased in steel canisters averaging 12 inches in diameter and 10 feet long. Thus, solidification and encapsulation must occur prior to initiation of most disposal schemes.

Four solidification processes have been developed in the United States to the point of demonstration on an engineering scale:

- fluidized bed calcination
- spray solidification
- pot calcination
- phosphate glass solidification

In all four processes, heat is applied to drive off volatile constituents (primarily water and nitrates) which results in either a calcined solid or a melt that will cool to a monolithic solid. The latter generally requires dilution of the waste with 20 to 40 percent nonradioactive materials such as glass or ceramics that have low solubility in water and are fusible at temperatures of less than about 1200°C.

Characteristics of typical final solid waste forms from the four processes are shown in Table 7, and are described briefly below.

Fluidized Bed Calcination. Liquid waste is atomized into a heated fluidized bed where it is deposited and calcined on granular bed particles. Resulting granular "spheres" of waste calcine may be the final waste form or they may be incorporated into crystalline or glassy solids in a melting stage.

Spray Solidification. Atomized droplets of waste fall through a heated chamber where flash evaporation results in solid oxide particles. Glassmaking solid frit or phosphoric acid can then be added to provide for melting and glass formation. The molten glass or ceramic is cooled and solidified.

Pot Calcination. Liquid is continuously added and boiled away in a processing vessel which also serves as the storage canister. When the canister is full of solids, the addition of aqueous waste is stopped and the solid is heated and held at about 900°C to complete denitration and dehydration. Feed additives can be used to result in a glass rather than calcine cake.

Phosphate Glass Solidification. Liquid waste and phosphoric acid are mixed and concentrated to a thick sludge in an evaporator. The sludge goes to a melter where dehydration and denitration are completed and the material is

TABLE 7

Characteristics of Solidified High-Level Waste

	Pot Calcine	Spray Phosphate Ceramic	Phosphate Glass	Borosilicate Glass[a]	Fluidized Bed Calcine
Form	Scale	Monolithic	Monolithic	Monolithic	Granular
Description	Calcine Cake, Friable	Ceramic	Glass Hard, Brittle	Glass Hard, Brittle	Calcine, Mean particle diam. 100-500 micrometers
Bulk Density (g/cm^3)	1.2 to 1.4		2.7 to 3.0	3.0 to 3.5	1.0 to 1.7
Wt% Fission Product Oxides (Max.)	90		25	50	50
Thermal Conductivity W/(m^2)(°C/m)	0.3 to 0.4	1.0 to 1.4	0.8 to 1.2	1.0 to 1.4	0.2 to 0.4
Leachability in Cold Water, g/cm^2-day	1.0 to 10^{-3}	10^{-3} to 10^{-5}	10^{-4} to 10^{-6}[b]	10^{-5} to 10^{-7}	1.0 to 10^{-1}

---

[a] Produced by either spray or fluidized bed calcining followed by melting, or by in-canister vitrification processing.

[b] Devitrified phosphate glass exhibits increased leachability (leach rates = 10^{-2} to 10^{-3} g/cm^2-day).

melted. Molten phosphate glass then drops into a storage canister where it cools and solidifies.

Disposal Concepts

Table 8 summarizes three areas of basic disposal concepts--ocean, geological and ice sheet disposal. The following descriptions of these three basic concepts, and others such as extraterrestrial and transmutation, have been summarized from various Energy Research and Development Administration (ERDA), Environmental Protection Agency (EPA), and Nuclear Regulatory Commission (NRC) documents.

The concepts described here include the most frequently discussed and proposed methods for disposing of radioactive waste materials. However, all of these alternatives possess the same major elements of risk: engineering failures; human failures; and unanticipated natural events.

Ocean Disposal Alternatives

Studies on ocean burial of radioactive wastes indicate that this concept has considerable merit. 6/ Most importantly, many ocean regions are not only isolated from human habitation, but are also biologically nonproliferating, geologically stable, and without resources of societal need. Additionally, areas have been identified which are isolated from natural disasters such as earthquakes.

The deep sea floor, including ocean basins and abyssal plains, are considered geologically stable. In some areas waste could be isolated in bedrock below the unconsolidated sedimentary cover. Large volumes of seawater would help cool the waste and provide high dilution for any material which accidentally escapes. Additionally, the high ion-exchange capacity of sea floor sediments would provide additional isolation barriers.

Subduction zones/deep sea trenches are areas where, according to crustal plate tectonics theory, one edge of certain crustal plates is moving under other crustal plates, and then down into the earth's mantle. Radioactive material could be buried in these trench areas and would be slowly subducted into the earth's mantle with the crustal plate.

High sedimentation rate areas, where major rivers are building deltas into the ocean, represent other sites where waste could be buried in the bedrock below the accumulating deltaic sediments.

Solid radioactive waste management systems for seafloor disposal are difficult but manageable. Wastes could be encapsulated without prior partitioning of the different radioactive materials. Solidified and canned bulk waste from the reprocessing plant would be packed in durable protective casks and loaded aboard special ships at special embarkation points. A control system at these checkpoints would maintain integrity of the waste canisters. Ships would be equipped to provide cooling as well as monitoring and examination of

TABLE 8

Summary of Nuclear Waste Disposal Concepts

	Characteristics						
	Potential				Practicality		
Disposal Concept	Placement Risk	Stability	Isolation	Invulnerability	Cost	Research Needed	Existing Tech.
Ocean Disposal							
Direct dumping in ocean	0* (0)	- (0)	- (0)	- (0)	+	+	+
Placement in ocean floor in abyssal hills regions	0 (0)	+ (+)	0 (+)	0 (+)	0	0	0
Placement in deep ocean trenches for subduction	- (-)	- (0)	+*** (+)	+*** (+)	-	-	-
Ice Sheet Disposal	- (-)	- (0)	- (0)	0 (0)	-	0	0
Geologic Disposal							
Liquid Injection	+ (+)	- (0)	- (0)	- (0)	+	+	+
Disposal in mined cavity in salt	+ (+)	+ (+)	+ (+)	- (+)	0	0	0
Disposal in deep holes	0 (0)	+ (+)	+ (+)	+ (+)	0	-	-
Extraterrestrial Disposal****	--	++	++	++	--	-	-

* + refers to positive attribute (high stability, low cost, etc.), 0 to intermediate attribute, and - to a negative attribute. Rating on basis of disposal on order of a million years.

** Values in parentheses are ratings on basis of disposal for 1000 years.

*** Ratings on basis that subduction has been achieved. Over much of life before subduction, rating would be much lower.

**** Includes disposal of actinides only. Remaining fission products would have to be disposed of using another method.

the waste canisters until arrival at the disposal site. Holes in the basement rock, about 800 meters in depth, would be predrilled on about 1.6 kilometer centers to allow for heat dissipation. About 100 waste canisters would be deposited into each predrilled hole. Disposal would be completed by filling and sealing the top 200 meters of the holes with cement or grout and by replacing the sediment. Area surrounding the disposal holes would be monitored for a specific period of time.

Since ocean burial would be an international issue, other countries involved in producing nuclear energy might find a common dumping area ideal for use among radioactive waste-producing nations.

Ice Disposal

Large permanent frozen masses of ice overlying continental land masses offer potential advantages as a disposal medium. The Antarctic ice sheet, which is International Territory, is a potential international repository. Large areas of massively thick ice are available at locations remote from human activities and with little chance of future development. Ice, provided its average temperature remains far below the freezing point, self-heals fractures. It has low permeability to water and a thermal conductivity comparable to common rock types. Biological activity is low. The natural capacity of the ice sheets to dissipate heat from radioactive waste canisters at low temperatures is conducive to maintaining integrity of the waste materials.

Three potential disposal concepts have been developed for ice sheet areas such as Antarctica or Greenland. These concepts, based upon managing the solidified high-level waste without partitioning, are:

- Meltdown or free flow. The waste canister is buried in an individual shallow drilled hole in the ice and allowed to melt down through the ice sheet to bedrock.

- Anchored emplacement. The waste canister is placed in an individual shallow drilled hole in the ice but remains connected to surface anchors by cables or chains.

- Surface storage/disposal. Waste canisters are placed in a shielded cell storage facility with jack-up piers on the ice sheet surface to provide heat removal to the ambient air and to prevent covering by further ice accumulation.

For the meltdown and anchored emplacement concepts, the canister is placed in a hole 50 to 100 meters deep. The canister descends by self-melting. Cables or chains, 200 to 500 meters long and attached to surface anchors, are tied to the canister for the anchored emplacement concept. These cables control the waste canister's descent and maintain its position for the required time period of about 100 years. Canisters are emplaced one per hole on 1-kilometer centers. This spacing would maintain total separation between canisters during descent. Disposal would be achieved by self-melting and refreezing of the ice above the canisters as they descend. The waste canister must be encapsulated to accomodate high pressures and prevent any possible leakage of the waste.

In the surface storage facility disposal concept, storage would be carried out by placing the canisters in a surface facility on the ice sheet. After about 50 years, the facility is allowed to become covered by accumulating snow and is eventually buried by accumulating ice and snow for final disposal.

Transportation presents potential hazards. The waste management system for all ice sheet concepts is characterized by transporting previously solidified and canned bulk waste in protective casks from the reprocessing plant to special embarkation ports. These ports would contain a receiving facility where the canisters would be inspected and placed in special protective casks for loading onto the transport ship. Sea transport would be by specially designed ship(s) with facilities for cooling, inspecting, and handling the waste canisters. The hull would be designed for protection against damage due to pack ice or related accidents. Ice-breaker escorts would be used for routine operation. The transport ship would operate outside normal sea lanes to reduce the risk of collision at sea and would dock and unload the casks onto the over-ice transport vehicles. The waste canisters and casks are then offloaded at a debarkation facility on land in an ice-free area near the edge of the ice.

Crawler-type tractors pulling sleds are, at present, the most dependable means of over-ice transport under the severe operating conditions of the ice sheet areas. However, other types of transportation may be used such as aircraft or surface effect vehicles (hovercraft), with fuel supplied by aircraft fuel drops. Hovercraft would require further development and testing to prove their capability for routine operation. Finally, the waste is emplaced at the disposal site. Area around the disposal site would be monitored for the required time period.

Geologic Disposal

Problems of burying radioactive waste in remote geologic environments have been intensively studied. Drilling, mechanical mining and dissolution, hydraulic fracturing, and controlled use of explosives are some methods which could be used. Table 9 shows ten conceptual methods for disposing of waste radioactive material. All involve burial in environments far removed from human and animal habitation for sufficient time to render the radioactive waste harmless. These environments must be stable, with little or no possibility of natural catastrophe such as earthquake or flood which might expose the waste to the atmosphere. Naturally occurring elements such as thorium and uranium have been isolated in this manner for millions of years. 7/

Form of the material to be disposed is an important consideration when studying geologic disposal methods. Solid waste appears to be the most feasible. In several concepts, waste is buried in the geologic formation as a

TABLE 9

Characteristics of Geologic Disposal Concepts

Concept	Type of Cavity	Waste Form at Time of Emplacement	Fluid Cooling	Waste-Rock Reactions
1	Mined	Solid	No	No
2	Mined	Solid	Water	Melt
3	Mined[a]	Solid	Air[c]	No
4	Mined[a]	Solid	Water[c]	No
5	Mined	Liquid[b]	No	Melt
6	Exploded	Liquid[b]	No	Melt
7	Matrix of Drilled Holes	Solid	No	No
8	Deep Hole	Solid	No	No/Melt[d]
9	Deep Hole	Liquid[b]	No	Melt
10	Hydrofracture	Liquid[b]	No	No

---

[a] Includes underground man-made structures.

[b] All liquid emplacement concepts involve in-place conversion to a solid form.

[c] Cooling is provided for an interim period of tens of years until the heat generation rate has decreased to a point where melting will not occur.

[d] This deep hole concept is studied for both melting and non-melting cases.

liquid and then converted in place to a solid form for long-term disposal. Under concepts 5, 6 and 9 in Table 9, liquid waste melts the surrounding rock and, upon cooling, forms a solid waste rock matrix. Concept 10 indicates liquid waste being incorporated within a self-curing cement.

In all of these concepts, transport presents serious and difficult hazards when shipping aqueous high-level waste. Therefore, liquid emplacement concepts require that fuel reprocessing plants be located at the disposal site. Solid wastes are less hazardous to transport. If conversion to a solid occurs at the fuel reprocessing plant, federal disposal sites can be at a separate location from the reprocessing plant.

In addition to the general geologic disposal methods, numerous variations have been proposed, the most important of which are reviewed below. 8/

(1) Solid waste buried in mined cavity--no fluid cooling or melting. Previously solidified waste is buried in the floor of rooms or tunnels excavated in geologic formation. This approach is similar to the bedded salt disposal concept studied over the past 15 years. Casks filled with radioactive wastes are brought to the site by special carrier and lowered into a shielded handling cell. Individual canisters are removed from the cask and transported to a shaft. Cables lower the canisters into the subsurface complex.

At the mine level, individual waste canisters are moved from the subsurface shielded cell into a shielded transfer vehicle. The subsurface transfer vehicle receives the canister and transports the waste package to a previously mined burial tunnel with predrilled holes in the floor. The transfer vehicle is located over a hole, and the waste package is lowered into the hole. The top 6 to 8 feet of the hole is filled with a sealant to provide isolation and shielding. Heat from the waste is designed to be conducted through the geologic formation without causing melting or deterioration of the geologic media.

(2) Solid waste emplaced in mined cavities--interim liquid cooling and conversion to rock-waste matrix. Waste canisters are removed from shipping casks in a waste receiving facility, lowered through a drill hole into a lined cavity, and deposited on the cavity floor in a random array. Waste within the cavity is immersed in a boiling water bath. The steam which is generated is condensed in a surface facility and returned to the hole for cooling the waste. Operation of the surface cooling system is continued until the cavity contents melt by allowing the cooling water to boil away. Cavity shutdown is started by stopping return of the condensed steam. The cavity begins to dry and the temperature of the contained materials rises. The cased hole is sealed at an appropriate time, and the waste is allowed to melt. The waste is concentrated in a small volume with little cooling by the surrounding rock and will thus melt from its own heat within a few days. The heat from the waste will melt some of the surrounding rock and form a larger molten mass which dilutes the waste concentration. This process occurs over a 100-year period. After a few hundred years, the molten rock-waste mixture will cool and solidify into a rock-waste matrix as the heat provided by radioactivity diminishes.

(3) Solid waste emplaced in man-made structures within geologic foundations--interim air cooling. Inside the bottom of a thick-walled metal pod buried in the floor of the tunnel, a canister of waste is sealed. Operating personnel are shielded from radiation. Radioactive decay heat is conducted through the metal pod wall and dissipated from the finned surface to the flowing cooling air. The single pass cooling air flows by natural convection once the draft has been initiated.

At the repository, a waste canister is unloaded inside a building and transferred to the underground facilities. At the mine level, the waste canister is placed in the containment pod. The pod is then placed in a hole or trench within a tunnel. The hole is backfilled with crushed rock, and the top of the pod is sealed. Other emplacement operations are similar to those for concept (1).

(4) Solid waste buried in man-made structures in geologic formations--interim water cooling. A man-made facility designed to withstand earthquakes and shifting rock formations is tunneled underground. The waste canister is unloaded at the repository, transferred to the below-ground facility, transported to the disposal location through the waste canister handling area of the tunnel, and lowered into the hole in a manner similar to the concepts above. The waste is placed in the shielded lower part of a cylindrical water-filled storage vessel in the mined cavity. Typically, the concrete shell would be 30 feet in diameter; the tunnel, 50 feet in diameter. Steam generated by the waste is piped to a heat-exchange system at the earth's surface where it is condensed and returned to the waste storage area. A side stream of the coolant is treated to remove any radioactivity which may be present from leaking or externally contaminated canisters. After a predetermined time, the cooling water is removed from the system. The access areas are sealed, and the waste heat is transferred to the surrounding rock without melting, as in concept (1) above.

(5) Liquid waste buried in a mined cavity--in-place drying and conversion to rock-waste matrix. Liquid waste is stored in a mined cavity below the fuel reprocessing plant. The cavity contains a high-integrity liner or tank connected through high-integrity piping to a specially designed condensing and treatment facility for the radioactivity-containing vapor. This facility would be located adjacent to the fuel reprocessing plant at the surface. Liquid waste is added continuously to the cavity and cooled by recycling condensed vapors from the surface facility. When the reprocessing plant is to be closed or the cavity is to be converted to its permanent disposal mode, the recycle of the condensed coolant is stopped and the cavity contents are allowed to boil to dryness and to melt. After assurance that no excessive pressure will develop in the cavity, the access shafts and piping are sealed. During a hundred-year period, the waste will melt the liner and some of the surrounding rock. After several hundred years, the molten rock-waste mixture will cool and progressively solidify into a rock-waste matrix.

(6) Liquid waste buried in exploded cavities--in-place drying and conversion to rock-waste matrix. This concept, similar to concept (5), is based on the formation of an unlined, rubble-filled cavity formed by nuclear explosion (or

possibly by conventional explosive). Rock rubble filling the cavity furnishes material for initial formation of the rock-waste matrix.

(7) *Solid waste emplaced in a matrix of drilled holes--no melting.* All operations in this concept are performed from the earth's surface. Canisters full of solidified high-level waste are brought to the handling facility and transferred to a specially designed transfer and emplacement (charging) vehicle. The vehicle moves to a previously drilled hole where each waste canister is carefully lowered into the hole and placed on the preceding canister. After the hole is filled with waste canisters to a predetermined level, the hole is sealed, and waste is emplaced in the next hole of the array.

(8) *Solid waste emplaced in a deep hole--in-place conversion to a rock-waste matrix*. Similar to the previous drilled matrix hole concept, this approach has each hole drilled to an extreme depth, nominally 16 kilometers (10 miles) deep. The concept can be designed for non-melting or melting. For the melting situation, the capability for handling vapors from volatilization of small amounts of water in geologic formations may be required within the surface facility. The waste in the lower portion of the hole will be molten while waste is added from above. After each hole is filled to the predetermined level with waste canisters, the hole is sealed. A few hundred years after emplacement of the waste, the molten waste-rock mixture will cool and solidify into a tall column of rock-waste matrix.

(9) *Liquid waste emplaced in a deep hole--in-place drying and conversion to a rock-waste matrix*. This concept, also similar to concept (5), uses *very* deep (16 kilometer) holes. The deep hole is drilled at the reprocessing plant site. Liquid waste is continually added to the hole, and vapor from the hot waste is removed in a vapor-condensing facility at the surface. A layer of dried and calcined waste is located below the small pool of boiling aqueous waste. Molten waste and melting rock form a layer below the layer of calcined waste. When one hole is filled to the predetermined level (assumed in this study to be the lower 7,500-meter portion of the hole), a second hole is used; waste in the first hole is allowed to dry, and the hole is sealed. After a few hundred years the molten waste-rock mixture will cool and form a waste-rock matrix.

(10) *Liquid waste emplaced by hydraulic fracturing--in-place conversion to a solid*. Liquid waste is mixed with cement grout to form a slurry which is pumped into a well under pressure. The pressurized slurry spreads out to form and fill thin horizontal fractures in the geological formation. These fractures were previously initiated by forcing water at high pressure to fracture the rocks along the bedding planes. The slurry cures in place within a few days and forms a sheet of solid waste-cement mixture about 3 millimeters thick and 350 meters in diameter around the well. Several layers of the sheets of waste-cement can be emplaced one above the other, before sealing the access hole and moving to another well location. Operations are all conducted at the surface from a shielded cell facility. Dilution and heat transfer conditions are designed to maintain the waste and rock at low temperatures (100°C or less).

Extraterrestrial Disposal and Transmutation

Both extraterrestrial disposal and transmutation offer considerable future promise because of the low societal risk associated with their application. In both concepts, the risks attendant to unanticipated natural events are negligible. However, neither concept can be implemented at present, as appropriate technology for these alternatives has not yet been developed.

Extraterrestrial disposal concepts. Assuming that a stable non-earth intercept trajectory or orbit can be achieved, extraterrestrial disposal offers complete removal of long-lived nuclear waste constituents from earth and the potential for an international solution to waste management.

In considering extraterrestrial disposal concepts, disposal of only the transuranic elements appears to be most practical because of the high shielding weight of the disposal systems, the complex cooling systems required, and the high space transport cost per unit of weight (at least $2000/kg of waste material). Adverse features of this concept are: (1) only part of the waste is considered; (2) possible launch safety problems; (3) retrievability and monitoring are difficult; and (4) the concept would require international agreements.

The overall waste management system would consist of interim aqueous waste storage to allow for decay and simplification of partitioning. Partitioning of the aqueous waste would result in a transuranic element fraction contaminated by no more than 1% of the fission products, with remaining waste to be disposed of by an alternative method. This actinide waste would be converted at the reprocessing plant to a refractory oxide and then encapsulated into high-integrity, multiple-barrier capsules. The capsules would then be transported overland to a space launch site.

The waste would be launched into space to an initial low-earth orbit (150 to 500 kilometers above the earth) with a reusable space shuttle. From this orbit, a space tug or upper stage(s) would be launched to carry the waste package to its final destination. In some cases, the launch system could inject the waste to its final destination without subsequent course correction. In other cases, the waste tug would require subsequent mid-course corrections or propulsion. Monitoring would be required to control for off-standard events and radioactivity in the upper atmosphere.

Transmutation elimination. Transmutation is the changing of one isotope into another by any means. For waste management, transmutation results in a product isotope having a lower toxicity and/or a shorter half-life than its predecessor. Ideally, radioactive constituents in high-level waste could be eliminated by using nuclear processes themselves to achieve the transmutation. More practically, the transmutation process would accelerate decay of radioactive waste by converting long-lived radioisotopes to other isotopes which have shorter decay times. If this can be achieved, both the quantity of waste containing long-lived radionuclides and the time required for safely storing treated radioactive waste would be significantly reduced.

The waste management system for waste actinides includes a period of interim aqueous storage to allow for decay and to permit improved partitioning into an actinide waste stream and a short-lived residue. At the reprocessing plant, actinides are converted to oxides. These are then converted into special recycle fuel forms. Finally, the actinide fuel is transported to a fission reactor for irradiation. The remaining short-lived fraction must be disposed of by an alternative method.

Transmutation using fusion reactors may be feasible at some later time. The concept is similar to the above, except that the aqueous waste stream would be partitioned into two or more streams containing waste actinides, possibly selected fission products, and a residual waste stream to be eliminated by other methods. The waste streams for transmutation would be converted into solid fuel materials (probably oxides) at the reprocessing plant. Fuel materials would be fabricated into special target elements, which would be inserted into the blanket of a fusion reactor for irradiation as part of the reactor fuel cycle. Continued recycle of material which undergoes transmutation would also be part of this operation. Waste streams not sent to transmutation must be disposed of by other means. In addition, the "heel" of untransmuted actinide waste at the termination of a nuclear plant era must also be rendered harmless.

A complete transmutation strategy for management of high-level waste assumes a three-phase development approach:

-- In phase 1, long-lived actinides are converted to short-lived fission products. The normal nuclear fuel-cycle of the fission reactor industry retains all actinides within this cycle and thereby converts a significant part of the actinides into fission products by transmutation. Partitioning the waste is the most significant modification to the fuel cycle.

-- In phase 2, fission products are placed into temporary retrievable storage, to be used in the next step in the process.

-- Phase 3 transmutes in a fusion reactor the long-lived fission products and actinides accumulated from the fission reactor cycle. This final phase eliminates most long-lived radioactive waste constituents.

Notes to Chapter 12

1. T. Hollocher, "Storage and Disposal of High Level Wastes," in: Union of Concerned Scientists. The Nuclear Fuel Cycle. . ., pp. 219-275.

2. H. P. Metzger, The Atomic Establishment (N.Y.: Simon and Schuster, 1972).

3. U.S. Energy Research & Development Administration, Alternatives for Managing Wastes from Reactors and Post-Fission Operations in the LWR Fuel

Cycle, Report coordinated by Battelle Pacific Northwest Laboratories for the Division of Nuclear Fuel Cycle and Production, U.S. Energy Research and Development Administration. (ERDA 76-43) 1976. Vol. 1, p. 9.

4. U.S. Nuclear Regulatory Commission, *Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle*, October 1976; NUREG 0116 (Supp. #1, to WASH-1248), p. 4.24.

5. U.S. Energy Research & Development Administration, *Alternatives for Managing Wastes. . .*, Vol. 3, p. 19.1.

6. U.S. Nuclear Regulatory Commission, *Environmental Survey of the Reprocessing and Waste Management Portions*. . ., p. 4.121.

7. U.S. Energy Research & Development Administration, *Alternatives for Managing Wastes. . .*, Vol. 3, p. 20.1.

8. U.S. Energy Research & Development Administration, *Alternatives for Managing Wastes*. . ., Vol. 1.

13. Risk Issues Associated With Nuclear Waste Management

The alternative nuclear waste disposal concepts discussed in Chapter 12 were all characterized by essentially the same risk elements. This chapter analyzes risk issues associated with nuclear waste management in more explicit detail. It also discusses the unique characteristics of nuclear waste which affect the risk features and social decision-making in the face of such risks.

Nature of Societal Risks Associated with Nuclear Waste

The principal societal risk resulting from nuclear waste is that of accidental release of radiation which can affect all living organisms, specifically human health. The Biological Effects of Ionizing Radiation report (BEIR Report) estimates that the cancer risk by radiation to an individual organ such as the lung or bone is about 1×10^{-6} cancers/year per rem dose to the organ, and about 5×10^{-6} cancers/year per rem dose to the whole body. 1/ The BEIR results can be used to determine cancer risks. However, for continuous exposure over a lifetime, which must be assumed if the ocean is contaminated, the actual risk to an individual would depend upon type and timing of exposure, as well as age of the individual at exposure. The BEIR Report suggests that the cancer induction rate is maintained for a 30-year period beginning 15 years after the irradiation (latent period).

In the case of exposure to bone from isotopes such as strontium and the actinides, the 50-year dose commitment is received essentially continuously over the individual's lifetime, meaning only about 1/50 of the dose is received per year. However, this figure is compensated by the assumption that people will continue to be exposed to the isotopes over their entire lifetimes. Thus, in the 50th year of exposure, the yearly exposure rate will equal the 50-year dose commitment. When this observation is considered with data from the cancer model proposed by the BEIR Report, and people of different ages are considered (a uniform population distribution by age is assumed), the average cancer risk per year for an average person from continuous uptake is 6×10^{-6} cancers/year per rem to the bone from a single year's uptake (using the ICRP re values which are really 50-year dose commitment values); 20×10^{-6} cancers/year to other organs; and 100×10^{-6} cancers/year per rem to the whole body. Using these values, the individual cancer risks for the three different time scales can be summarized as follows:

- Short term:	6×10^{-7} cancers per year
- Intermediate term:	6×10^{-7} cancers per year
- Long-term:	10×10^{-9} cancers per year

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Cancer risks noted above are only for those resulting from radiation discharge in water. These figures represent the single highest risk from radiation, however, and thus would also be the probable ultimate risk for radioactive wastes released to other media. According to the BEIR Report, the following four cases can be established to indicate the range of overall health impact from nuclear waste radiation.

Case 1. Complete release of the total waste inventory, assuming no fractionation or recycle of any waste materials, over an average period of 1000 years.

Case 2. Complete release of the total waste inventory, assuming fractionation and recycle of 99.5% of U, Pu, Np and 99% of Am, Cm, I, Tc, over an average period of 1000 years.

Case 3. Complete release of the unfractionated waste inventory over an average period of a million years.

Case 4. Complete release of waste fractionated as in Case 2 above over an average period of one million years.

The above risks do not appear to be significantly greater than those associated with many other human activities. Further, the above discussion should clearly indicate that any societal risk from nuclear wastes results only if radiation is released from nuclear waste dispositions. Factors that may influence or cause such release are discussed below.

Factors That May Contribute To Radioactive Release From Nuclear Waste

As discussed in Chapter 12, all alternative nuclear waste disposal concepts are intended to answer the physical integrity of the disposal site. Three major factors that cause and/or contribute to radiation release from nuclear waste deposition are:

- engineering and component failures

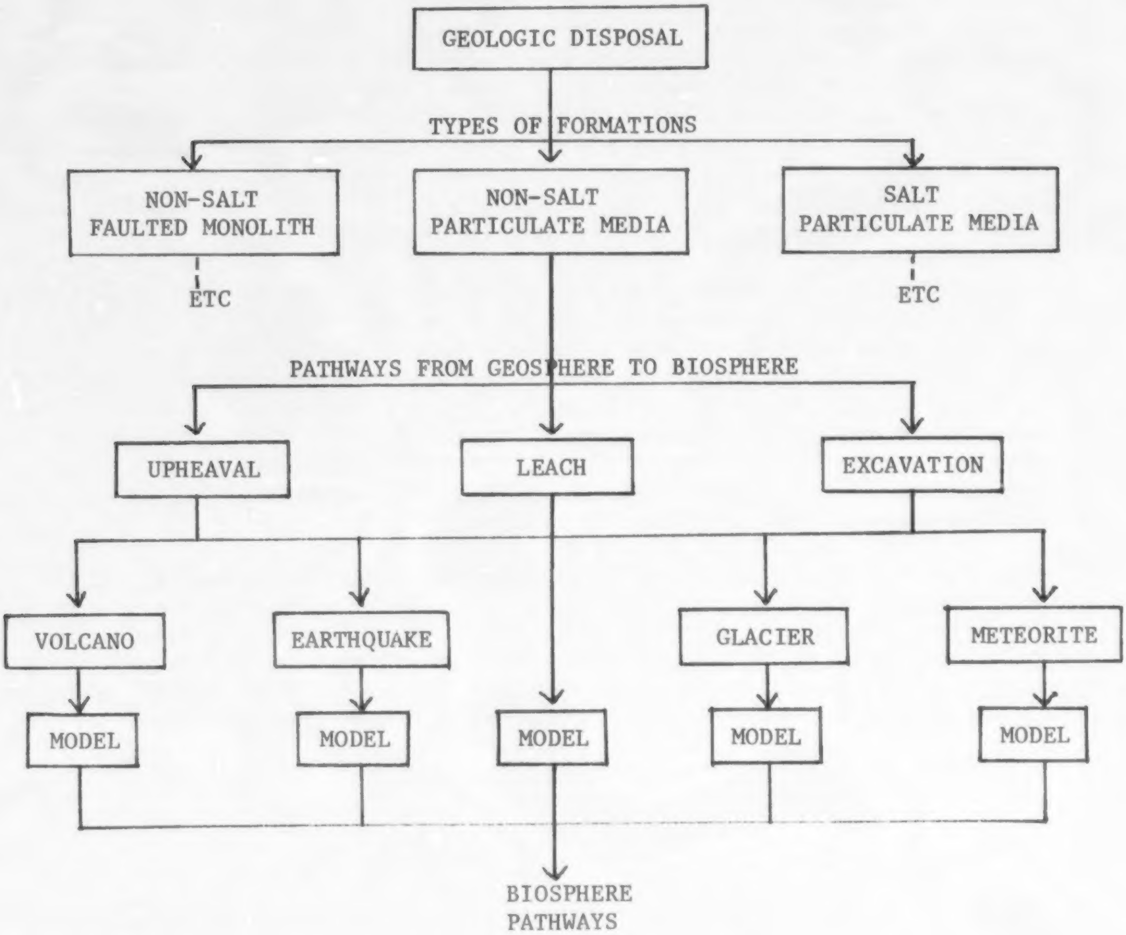
- human errors

- unanticipated natural events

These major factors are discussed in the specific evaluation of risk analysis methodology detailed in Chapter 16. Secondary factors, of course, cannot be ignored. Certainly there are events which could occur that would result in release of radiation from geological disposal--geosphere to biosphere. A schematic diagram of such events is presented in Figure 3. However, factors that cause and/or contribute to release of radioactivity from nuclear waste depositories are relatively few in number and conceptually not difficult to analyze and assess. The complexity in nuclear waste management and in assessing the societal risks results from the unique characteristics of nuclear waste.

FIGURE 3

Geological Disposal From Geosphere Migration Point Of View*


GEOLOGIC DISPOSAL
TYPES OF FORMATIONS
NON-SALT FAULTED MONOLITH
NON-SALT PARTICULATE MEDIA
SALT PARTICULATE MEDIA
ETC
ETC
PATHWAYS FROM GEOSPHERE TO BIOSPHERE
UPHEAVAL
LEACH
EXCAVATION
VOLCANO
EARTHQUAKE
GLACIER
METEORITE
MODEL
MODEL
MODEL
MODEL
MODEL
BIOSPHERE PATHWAYS

*Source: Bradishaw, R. L. & W. C. McClain, "Project Salt Vault: A Demonstration of the Disposal of High-Activity, Solidified Wastes in Underground Salt Mines," ORNL-4555, 1971.

Unique Characteristics of Nuclear Waste

Two characteristics contribute to analytic and data difficulties of nuclear waste management more than any other. First, nuclear waste remains potentially hazardous for a very long time span, thereby creating severe intergenerational effects. Second, certain waste management decisions are irreversible.

The time during which the waste remains active is indeed enormous, spanning hundreds of thousands of years for long-lived wastes. The magnitude of this span can be better comprehended by comparing the required control time for nuclear waste management with other characteristics of natural ages, as shown in Figure 4. Further illustration of this long time span can be seen from the curves that indicate the hazard index of spent fuel as a function of age, shown in Figure 5. Because management decisions regarding nuclear waste are without precedent in managing public policy, this lengthy time span must be recognized and considered, creating formidable conceptual, methodological and data problems that render most benefit-cost or benefit-risk analysis unreliable in relation to nuclear waste management.

An additional consideration is the problem of setting appropriate interest rates in benefit-cost analysis (discussed in more detail later in this report). The root of this complexity lies in one component of the real interest rate: risk premium. As stated, the risks of nuclear waste disposal can be large for all of present and future society. It is extremely difficult to derive the shape of utility functions toward risk for future generations over the span of this long time period. Therefore, long-term benefit-cost analysis cannot be used since the results of such analysis are highly sensitive to the interest rate.

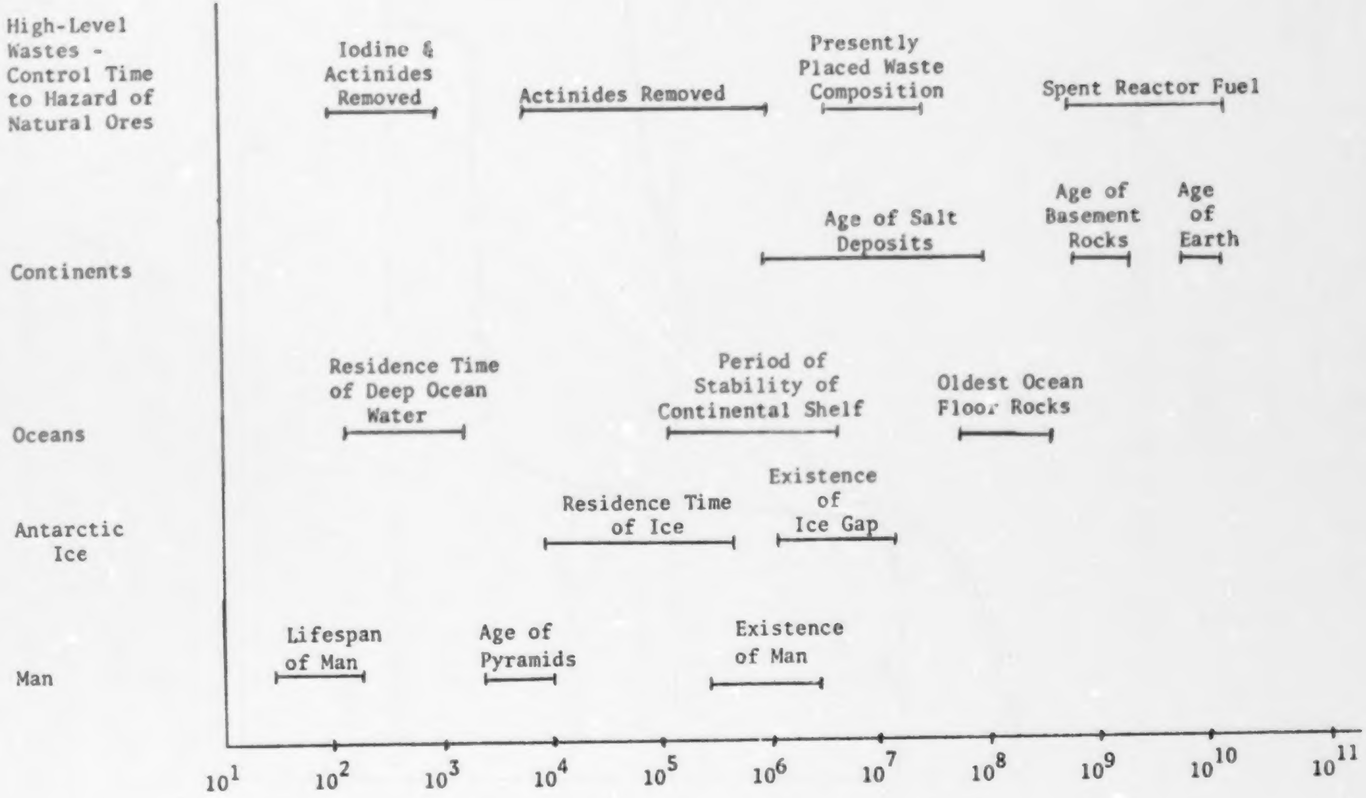
Two additional elements that contribute to the difficulties of undertaking meaningful benefit-cost or related analysis of nuclear waste disposal are the relatively complicated legal framework of nuclear waste management, and the ambitious, albeit incomplete, Federal Government radiation protection criteria. Analysis of both of these elements and their relationship to analysis of societal risk management appears in the following Chapter.

Note to Chapter 13

1. National Academy of Sciences-National Research Council, Division of Medical Sciences, Effects on Populations of Exposure to Low Levels of Ionizing Radiation, Report of Advisory Committee on Biological Effects of Ionizing Radiation . (Washington, D.C.: National Academy of Sciences, November 1972). This report is frequently referred to as the "BEIR Report."

FIGURE 4

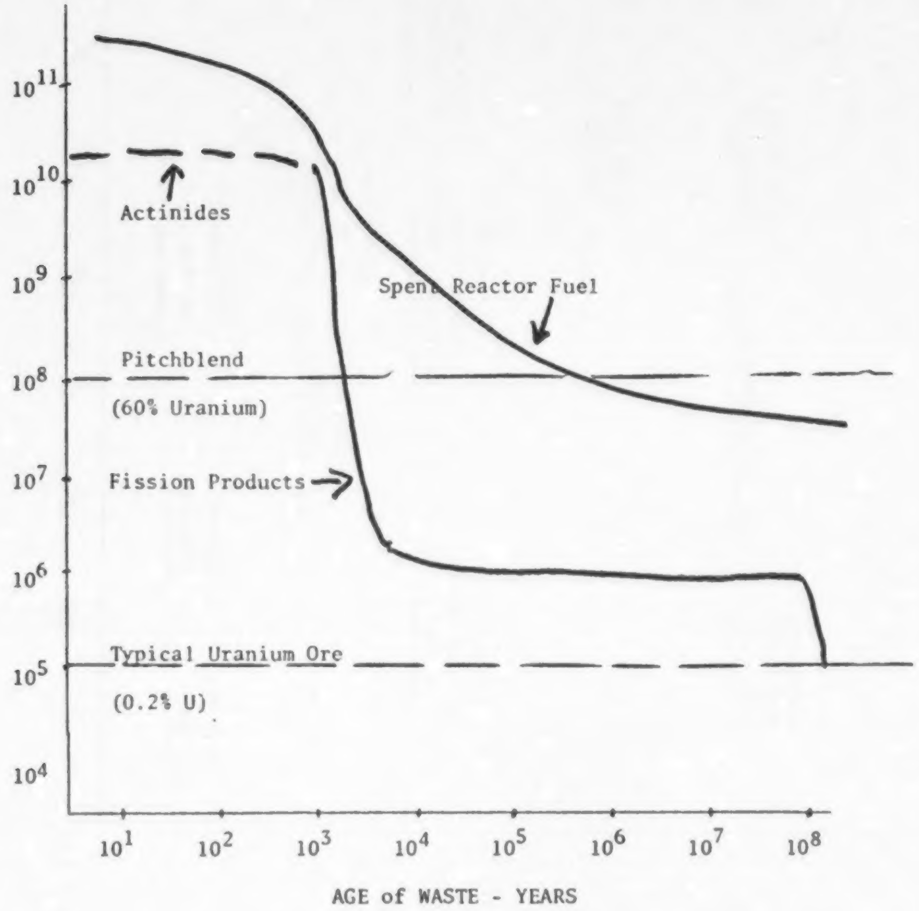
Comparison of Characteristic Natural Ages with Control Time of High-Level Waste*



*Source: General Accounting Office, "Isolating High-Level Radioactive Waste from the Environment: Achievements, Problems, and Uncertainties," RED-75-309, December 1974.

FIGURE 5

Hazard of Spent Fuel as a Function of Age*



*Source: Gera, F. and D. G. Jacobs, Consideration in the Long-Term Management of High Level Radioactive Wastes, U.S.A.E.C. Report, ORNL 4762, Oak Ridge National Laboratory, Tennessee, 1972.

14. Legal Framework and Federal Criteria for Nuclear Wastes

This chapter gives a brief account of the legal framework for nuclear waste disposal plus a detailed discussion of current Federal Government radiation protection criteria. These two subjects, in the context of waste disposal concepts, have differing impacts on analysis of risk. Impact of the legal framework is quite explicit and clear. Conversely, because radiation protection criteria are still in a state of evolution and refinement, their impact is less clear and may undergo considerable change in the future. Nevertheless, these important criteria cannot be neglected.

Legal Framework for Nuclear Waste Management

Radioactive waste is one group of a large number of waste materials considered hazardous. Several federal and state statutes pertain indirectly to management of radioactive waste through controls established for hazardous wastes management. Other federal statutes, such as the Atomic Energy Act of 1946 and Amendments in 1954 and the Energy Reorganization Act of 1974, have more direct impacts on management of radioactive wastes. The Supreme Court has ruled that states may not regulate emissions from nuclear plants. 1/ As a result, uncertainty exists regarding the extent to which states can directly affect management of radioactive wastes.

For many years the most important government agency affecting development of nuclear energy and, consequently, management of radioactive wastes, was the Atomic Energy Commission (AEC). This Commission was established by the Atomic Energy Act of 1946, and abolished in 1974 by the Energy Reorganization Act. The AEC functioned as both promoter and regulator of nuclear energy. In this dual capacity, the Commission was thought by some to represent a conflict of interest, 2/ which later proved to be one cause for its abolishment. The Energy Reorganization Act established two agencies: (1) the Nuclear Regulatory Commission (NRC), which was given the regulatory function of the AEC; and (2) the Energy Research and Development Administration (ERDA), which assumed the promotion function of the AEC. Subsequently, the Department of Energy (DOE), created by the Carter Administration in 1977, absorbed ERDA.

The Atomic Energy Commission. The Atomic Energy Act of 1946 established the Commission to control development of atomic energy. 3/ At that time atomic energy held great potential as a source for electrical energy and for national defense. Accordingly, the Commission was given enormous powers, unprecedented in American history. The scope of its powers was suggested by the legislation's specifications that the Commission alone could own certain nuclear materials. 4/

In 1954, the Atomic Energy Act of 1946 was amended to allow private industry and the public to participate in development of nuclear resources for production of electrical energy. The AEC's role was relaxed slightly from total control to that of promoting and regulating development of nuclear energy. It became possible for private industry to own reactors and other facilities, all of which were subject to licensing and other regulations imposed by the AEC.

AEC's purpose was to assure that nuclear energy made a maximum contribution to national defense and contributed to the general welfare. To achieve these goals, the Commission developed programs:

a. To conduct research projects and assist in related projects initiated by government and private enterprise.

b. To disseminate unclassified information and to declassify certain restricted data for dissemination.

c. To encourage widespread participation in development and utilization of nuclear energy for peaceful purposes to the maximum extent consistent with common defense and security, and with considerations for public health and safety.

The AEC was responsible for granting, suspending, revoking, or taking other appropriate action regarding the licensing of facilities, issuing of construction permits, or transferring a license from one party to another. In 1961, the AEC established an office of the Director of Regulations, and divided its staff into two units: regulations and operations. Heads of both units, the Director of Regulations, and the General Manager, reported directly to the Commission.

Applications for licenses or amendments to existing licenses had to be filed with the Director of Regulations. Separate licenses were required to construct and operate a nuclear facility. Parties intending to file application for either kind of license had the option of conferring informally with the regulatory staff prior to filing such application.

The Atomic Energy Act required that each application for a license contain all information that the Commission deemed necessary to reach a decision. These requirements included information on the financial and technical qualifications of the applicant, as well as character and citizenship. In addition, the application had to contain technical information, such as the kind, quantity and source of the nuclear material required; intended location of the facility; specific characteristics of the facility; and a preliminary safety report (PSAR).

Applicants for a license to operate a power plant or radioactive waste management facility had to provide the chief executive of the municipality or the county in which the facility was to be located with a copy of the application filed with the AEC. The Director of Regulations also sent a copy of the application to the Governor of the State in which the facility was to be located and arranged to have a receipt of the application published in the Federal Register.

The regulatory staff, with assistance from the operating staff, reviewed the application to determine whether the proposed facility complied with national security, public health and safety goals of the AEC. The staff had to follow the Administrative Procedure Act, excluding the requirements for classified information. 5/ The Justice Department had to be consulted for advice on antitrust matters. 6/ The Environmental Protection Agency had to be solicited for advice on public health. 7/ In addition, the Commission had to follow the procedures and implement policies of the National Environmental Policy Act (NEPA). 8/

Usually, the first problems encountered by the Regulatory staff involved inadequate information. Moreover, the applicant's evaluations of certain aspects of the facility often differed from the staff's evaluations. 9/ The staff would attempt to resolve these differences through conferences and written communication with the applicant.

The Advisory Committee on Reactor Safety (ACRS) would also review the application regarding public health and safety, and would report its findings in the form of a letter addressed to the Chairman of the AEC. The Regulatory staff would use all of the information in preparing a Final Detailed Statement on Environmental Considerations.

Prior to issuing a construction permit, a mandatory public hearing was conducted by the Atomic Safety and Licensing Board. Another public hearing was necessary prior to issuing an operating license if the licensing was contested. Final decisions of the Commission to issue either a construction permit or an operating license were reviewable in a Court of Appeals. 10/

The public hearing was the AEC's official mechanism for public input. The scope of each hearing was established by the AEC. Intervenors often regarded the scope as too restricted and raised issues, such as the effects of waste disposal and alternatives of purchasing electricity elsewhere or using less electricity, but the relevance of such issues was not finally resolved. 11/

Another problem perceived by intervenors concerned the AEC's rule for implementing policies of the National Environmental Policy Act. In the landmark case of Calvert Cliffs' Coordinating Committee vs. AEC 12/, the Court of Appeals for the District of Columbia found that the Commission's interpretation of the NEPA improperly limited consideration of environmental values in the Commission's decision-making process. 13/ Prior to this case, water quality questions could not be considered at the hearing, and other environmental effects were considered only if contested. 14/

The AEC prohibited any construction at nuclear power plant sites until a construction permit was issued. This prohibition banned all activities which would adversely affect the natural environment at the site, including cleaning of land, excavation, or construction of non-nuclear support facilities. 15/ Certain other activities, such as preconstruction monitoring to establish background information related to suitability of the site or to protection of environmental values, were permitted. This included geologic, seismic, hydrologic, and meteorologic investigations, as well as building such roads and physical structures as were judged reasonably necessary for determining site suitability. 16/ Once construction of the facility began, the AEC also had the authority to order changes to the facility while under construction, if such changes were economically justified. 17/

The Atomic Safety and Licensing Board stipulated the conditions under which the facility would operate, in accordance with technical analysis of the safety features. The Board usually set upper and lower operating limits on the facility and a maximum number of years over which the plant would be operated, not exceeding 50 years. 18/

Other Federal legislation. As noted previously, regulatory and promotional functions of the AEC have been taken over by the Nuclear Regulatory Commission and the Department of Energy, respectively. Other federal agencies with a role in radioactive waste management include the Departments of Transportation (DOT), Health, Education, and Welfare (HEW) and Environmental Protection Agency (EPA). Applicable statutes are (1) the Transportation of Explosives Act which prohibits transport of radioactive materials unless the public interest requires expedited movement or such transport poses no danger to life or property 19/; (2) the Hazardous Materials Transportation Act of 1970, and (3) the Hazardous Cargo Act which regulates water transport of explosives or dangerous substances. 20/

The Federal Clean Air Act authorized the Administrator of EPA to set standards on hazardous air pollutants at any level "which in his judgment provides an ample margin of safety to protect the public health." 21/ Finally, the Federal Water Pollution Control Act contains several provisions which directly affect management of radioactive wastes.

Legislation with the most critical impact on any analysis is, of course, the National Environmental Policy Act of 1965 (NEPA). The importance of NEPA for nuclear waste management results from requirements for execution of a detailed comprehensive benefit-cost analysis. The Act also permits intervention during the planning stages of nuclear waste deposition. Recent events clearly indicate the importance of such intervenors in public policy processes, and their presence adds measurably to the risk analysis requirements. These requirements are discussed further in Chapter 16.

As described above, several federal agencies have jurisdiction over nuclear waste disposal. This often makes interagency agreements necessary. Due to lack of a clear-cut division of responsibilities and authority, dispute occasionally arises regarding jurisdiction as well as responsibility. Inherent in this situation is a sometimes unnecessary duplication of effort.

Current Federal Government Radiation Protection Criteria: Their Applicability To Nuclear Waste Disposal

This section analyzes the most recent federal environmental protection criteria, as issued by the Environmental Protection Agency, which are most applicable to the guidance of radiation policy for operation of nuclear waste disposal activities. 22/

The Environmental Protection Agency is responsible for establishing "generally applicable environmental standards for the protection of the general environment from radioactive material." 23/ In this context the term "general environment" means "outside the boundaries of locations under the control of persons possessing or using radioactive materials." Promulgated standards specifically exclude waste management operations, and thus avoid certain technologically defined aspects of these operations. However, they serve as generic models for waste disposal protection criteria to be issued at a later date. 24/ It is important the the Environmental Protection Agency have these "generic models" on hand for assistance in formulating specific waste management criteria. Moreover, present criteria will probably require only "minor perturbations" to be applicable to the waste management portion of the fuel cycle. 25/

Ultimate objectives. A statement of objectives is a useful administrative guide for development of more specific criteria. Ultimately, these criteria will be refined to a point where decisions can be based upon them, and operations can proceed with a high degree of expected success. Objectives broadly defined are as follows:

(1) To protect the public against radiation doses resulting from fuel cycle operations.

(2) To limit the environmental burden of long-lived radioactive materials that accumulate as a result of producing electrical energy, so as to limit their long-term impact on both current and future generations. 26/

The first objective is to develop a standard which sets limits on annual doses of radiation. The second objective requires a standard to limit the burden of radioactive materials, the stock of the cause of risk. Final standards parallel this division of concern into the flow (annual dose) and stock of risk. Precise quantitative limits on annual dose and quantity of certain long-lived radioactive elements (in terms of their release per gigawatt-year of electrical power) are specified. Eight criteria used to implement, refine and modify the above objectives are discussed on pages 170-174, following the next subsection on secondary objectives.

Secondary objectives. Two further considerations have guided development of standards. First, a report by the National Academy of Sciences contained the judgment that "the current Guide is too high." 27/ This assessment was accepted by the Environmental Protection Agency, and resulted in more conservative standards. Second, language embodied in the Radiation Protection Guidance as well as many Congressional statutes requires that exposure be kept as "low as practicable." A judgment was made that this must be interpreted to mean that consideration could be given not only to radiation exposure, but also to costs of controls. Thus, from onset of the standards development process, dual and possibly opposing objectives existed: to lower the present radiation standard, and to consider the costs as well as the benefits or reduced risks of levels of exposure.

Eight criteria. Note that the decision process can be characterized in part as a cost-risk-benefit analysis. To some, cost-benefit calculations imply maximization of a single, well-defined objective function. Actually, the decision-making process is considerably more complicated. Various criteria have been developed and used to make decisions involving a number of tradeoffs among different objectives. Thus the decision process can be characterized as one of finding a set of standards that satisfy multiple criteria. The most important criteria are discussed here.

Criterion 1: Human Health

Radiation can harm all living species: mankind, animal life, and plants. Although all living organisms may be affected by radiation, standards were calibrated in relation to their effect on man alone, since "there is no present evidence that there is any biological species whose sensitivity is sufficiently high to warrant a greater level of protection than that adequate for man." 28/ Thus the analysis estimates potential health effects to humans as the measure of risk, rather than more general measures of quantities of radioactive materials.

Criterion 2: Consideration of Planned Releases Only

Since the Environmental Protection Agency is responsible for establishing performance standards, and the Nuclear Regulatory Commission is responsible for establishing operating standards to ensure accomplishment of performance standards, hazards of uncontrollable events are excluded from consideration. Control of normal operations to reduce planned effluents is only minimally "coupled" with the potential for accidental release of radioactive material. A separate process addresses the issue of accidental releases. A variance on the standards is proposed in case of "an emergency need for uninterrupted delivery of power," or "in the presence of a temporary and unusual operating situation." 29/

Criterion 3: Reduction of Total Potential Health Impact on Large Populations

The most important criterion is the aggregate dosage affecting various populations on a local, regional, national, or worldwide basis. 30/ Future and present populations are to be considered. This aggregate goal, which can be compared to maximization of national income in classical cost-benefit analysis, does not consider distributional effects. Within a given level of performance of this criterion, it does not matter whether the committed doses are shared equally or impact certain members of the population much more heavily than others. A central tenet of classical cost-benefit analysis is that such distributional considerations should be secondary. Undesirable distributional effects (at least those concerning money) can always be handled through income redistribution, provided the aggregate efficiency criterion is satisfied. However, when the analysis concerns health effects, it is much more difficult to claim that an avenue of compensation exists. Health is much less fungible than money. In general, a healthy person cannot give away part of his health to another.

The criterion as stated is unclear regarding relative weights to be assigned various populations. Whether people of the United States bear more heavily than other people in the world is not stated. More importantly, no balance is established between present and future generations.

Criterion 4: Distributive Effects Must Be Considered

Even though the aggregate dosage criterion is satisfied, an undesirable distribution may exist. 31/ Since the standards are environmental rather than occupational, this criterion addresses neighbors of particular site operations who may receive higher than average doses. Radiation emissions are distributed more heavily around nuclear operation sites, and it is therefore reasonable to expect that radiation doses will be distributed more heavily around sites. Since the incidence of health effects is assumed to be proportional to dosage, the total number of health effects should be invariant to the distribution of radiation doses. 32/ Given a level of aggregated health effects which satisfies Criterion 3, no health gains can be made by redistributing the burden of the dosage. An unfair situation is thought to exist, however, when some persons are exposed to much higher risks than others, particularly "when the individual at risk is not the direct recipient of the benefits of the activity producing them." 33/ This notion accords with two commonly expressed principles of equity.

First, society should be willing to pay far more to avoid involuntary risks. As individuals, neighbors of nuclear plants for the most part do not choose to live near a source of radioactive materials. Society should be willing to pay more to reduce risks to these persons than it may decide to pay for avoidance of risks to the United States population as a whole, who presumably have voluntarily accepted the risks of nuclear power.

A second implied principle of equity is less common. Many economists believe that persons working in more dangerous occupations demand and receive risk premia -- higher salaries in compensation for the higher level of risk on the job. Since these standards are environmental, belief in the equity of risk premia as fair compensation for more hazardous occupations is not a basis for accepting a maldistribution of risks from nuclear materials. The neighbors of atomic plants are not compensated for living near such plants. The benefits of nuclear power accrue to society in general, not to purchasers of the electricity produced by nuclear power, and certainly not to the neighbors of nuclear and fuel cycle operations.

If effects to individuals must be considered, the objective of minimizing the maximum individual dose alone might be considered. In this connection, economic factors must also be considered. Otherwise, the standards might "achieve negligible improvements in public health protection for unreasonably large investments in control technology." 34/

Criterion 3 indicates that the sum of overall health effects is to be minimized, giving due care to the distributive burden of radiation by Criterion 4. Answers are needed as to how far minimization of individual dose should proceed. These answers, in part, are provided by the next criterion.

Criterion 5: Reduction of Risks Must Be Cost-Effective

As previously mentioned, a secondary objective of the standard setting process was to consider not only minimization of radiation exposure but also cost of controls. The development of implicit criteria for the requisite cost-effectiveness trade-off is the primary subject of the following discussion.

Explicit guidelines to cost-effectiveness are not usually present in the final standards. Such guidelines are not necessary if the decision-making process is considered as something other than a cost-risk-benefit analysis. However, the polar dangers of ignoring cost and risk trade-offs are explicitly recognized. Excessively high radiation standards would expose the public to "unnecessary" health risks -- "unnecessary in the sense that exposures permitted by the standards can be avoided at a small or reasonable cost to the industry." 35/ On the other hand, standards would be too low if their control costs were "unreasonable in the sense that control costs imposed by the standards provide little or no health benefit to the public." 36/

Further, two possible options to avoid the difficult task of making cost-effectiveness choices are also discarded. First, it is recognized that no scientifically determined "acceptable" or "justifiable" level of health effects currently exists. Were such a criterion available, the decision process would be far more simple: only the technological task of determining "which controls should be used in order to meet that criterion at lowest cost" would need to be resolved. 37/ But, for the reason stated, cost minimization cannot be followed. Risk minimization is a second possible option. If only a specific amount of money could be spent for health protection, there would remain a relatively simple, value-free process of minimizing the number of health effects. 38/ However, neither an absolute health nor cost criterion exists, so the value-ridden trade-off between costs and permitted health effects must be made.

The Environmental Protection Agency approaches this problem by discussing several subordinate considerations that cannot be ignored. 39/ Since these considerations are classical constraints on choices in cost-benefit analysis, they are subsumed under the generic criterion that the reduction in risks must be cost-effective.

Criterion 6: Streams of Economic Expenditures Over Time Should Be Discounted to Present Values

In the analysis of various control options that might be required as a result of the proposed standards, capital and operating costs over the expected life of each system were determined as present values. This is common practice in cost-benefit analysis. Since purely economic resources are fungible over time, and since future costs to society are less burdensome than the same costs today, the discounting procedure seems unexceptionable. However, the question of the proper discount rate is left unmentioned. This criterion is thus incomplete.

Criterion 7: Streams of Health Effects Over Time Are Not Discounted, but Instead Are Summed with a Cut-Off at 100 Years

Although the standards are not intended to cover the major portion of the nuclear fuel cycle with long lasting effects (the disposal of wastes), they are applicable to a number of elements which will expose the population to risks over periods much longer than 100 years. The analysis includes consideration of the dangers from long-lived radionuclides:

> The total significance of (the) environmental burdens of carbon-14, iodine-129, and the long-lived transuranics, which have half-lives of 5700 years, 17 million years and from 18 years to 2 million years, respectively, cannot be quantitatively assessed, but must be assumed to be greater than that anticipated during the first 100 years alone. 40/

It is also recognized that the costs society is willing to pay to avert health effects depend in part on the timing of these effects:

> "The amount depends upon. . .how far into the future it (loss of human life) is anticipated to occur." 41/

Many economists would find serious flaws in the above criterion and its justification. There is an inherent contradiction in discounting operating costs but summing health effects. 42, 43/ Economic theory would concur that neither individual lives nor health are fungible or marketable. However, transactions exist which expend monetary resources and obtain increases in health or longevity. Hence money -- in a marginal sense -- is convertible into life and health. Society today spends money for hospitals, physician care, and medical research. This money can be saved, invested, and a greater dollar amount of similar health care purchased at a later time. In this sense, through the market back-door, economic equivalents to life and health exist and can be discounted.

What is inherently contradictory is to place the same (non-monetary) value on a life saved in 100 years as a life saved today, while completely neglecting the value of a life saved in 101 years. In fact, the results of the contradiction, though theoretically confused, accord with the views of economists who would have the analysis discount monetary equivalents of all lives saved in perpetuity.

If an upward bias is placed on the valuation of the stream of lives by not discounting, a downward bias is imposed by not counting the value of lives after 100 years. Given the state of uncertainty concerning expected health effects on lives after 100 years, the net effect of the two biases cannot be precisely determined. Given a constant valuation for life or health effects, however, the procedure of using undiscounted sums for 100 years is equivalent to summing discounted lives or health effects in perpetuity at some implicit discount rate. The implied discount rate can be shown to be quite low, probably well below that used to discount the monetary costs in the analysis. 44/ The effect of Criterion 7, therefore, is to weigh health effects more heavily than if economic costs and health effects were handled symmetrically, both using the same discount rate.

Criterion 8: Choice of a Cost-Effective Level of Control is Jointly Dependent on Technological Circumstances and Societal Valuations of Health and Life

Having avoided the issue of valuing life or health in computing the benefits of radiation reduction, the issue must rise anew when a choice on a health effects-cost trade-off curve must be made. The relationship between radiation control costs and reduction of health effects could be charted. For example, the health effects per gigawatt-year of electricity could be plotted against the cumulative present values of additional control measures, with this latter scale translated into incremental cost to the consumer in terms of mills per kilowatt hour. 45/ Health effects per additional million dollars of control equipment could then be plotted against the cumulative present worth and incremental costs to the consumer. 46/

At a certain point on a chart of this nature, "a breakpoint would occur between efficient and inefficient control options." 47/ The marginal cost for reducing potential health effects might be roughly $500,000, say, and a judgment then made that beyond this point "an insignificant further reduction in health effects is obtainable even for large additional control expenditures." 48/ The terms "insignificant" and "large" are, of course, defined only by values of the Environmental Protection Agency decision makers. Choice of a cost-effective level of control would appear to have been selected by examination of when the trade-off curve pitched steeply downward, and then further justified by a comparison with other estimates of the proper amount of resources to be spent for preservation of potential statistically defined lives.

A cost-effectiveness approach such as that just described does not find general agreement in other government studies and decisions. Moreover, no such cost-effectiveness level exists. Finally, cost-effectiveness cannot be a criterion for determining the degree or level of control.

Summary

The legal-regulatory framework within which decisions concerning disposal of nuclear wastes have been made was reviewed briefly. One of the more important developments has been the National Environmental Policy Act of 1965, which greatly enhanced the role of cost-risk-benefit analysis. This act, in conjunction with certain court decisions, has forced regulatory authorities to base nuclear decisions in a considerably broader context than before.

Eight criteria developed by EPA for radiation hazards in the environment were also reviewed in some detail. These criteria have been used to develop specific studies for environmental exposure to radiation. Although not specifically developed for nuclear wastes, at the time this study was undertaken they were the only environmental criteria in existence. Hence, they may well form the basis for subsequent development of criteria dealing explicitly with nuclear wastes. These criteria contain certain internal inconsistencies, as was pointed out, and in certain ways they appear somewhat general. However, as will be seen in the next chapter, they are far more detailed and specific than any criteria advanced to date by public interest groups.

Notes to Chapter 14

1. Northern States Power Co., v. Minnesota, Federal Reporter, 447F2d 1143 (1971), pp. 1143-1158.

2. Northern States Power Co., v. Minnesota,. . .

3. U.S. Atomic Energy Commission, Rules and Regulations, Title 10-Atomic Energy, Part 2, Rules of Practice, October 27, 1966, pp. 21-36.

4. W. C. Reynolds, The California Nuclear Initiative: Analysis and Discussion of the Issues (Stanford, CA: Stanford University Institute for Energy Studies, April 1976), p. 5.

5. Association of the Bar of the City of New York, Electricity and the Environment: the Reform of Legal Institutions, Special Committee on Electric Power and the Environment, Sheldon Oliensis, chairman. (St. Paul, Minn.: West Publishing Company, 1972), p. 69.

6. Association of the Bar of the City of New York, Electricity. . .

7. Association of the Bar of the City of New York, Electricity. . .

8. Association of the Bar of the City of New York, Electricity. . .

9. Steven Ebbin and Raphael Kasper, Citizen Groups & the Nuclear Power Controversy: Uses of Scientific & Technological Information (Cambridge, Mass.: MIT Press, 1974), p. 36.

10. Association of the Bar of the City of New York, Electricity. . ., p. 69.

11. Arthur W. Murphy, "The National Environmental Policy Act and the Licensing Process: Environmental List Magna Carta or Agency Coup de Grace?," Columbia Law Review, Vol. 72, October 1972, pp. 962-1007.

12. Ebbin and Kasper, Citizen Groups. . ., p. 30.

13. Calvert Cliffs' Coordinating Committee, Inc. v. Atomic Energy Commission, 449 F.2d 1109 (D.C. Cir. 1971).

14. Calvert Cliffs' Coordinating Committee v. Atomic Energy Commission at 1122.

15. Ebbin and Kasper, Citizen Groups. . ., p. 51.

16. R. Gannon, "What are the Dangers?" The American City, Vol. 71, (January 1972).

17. U.S. Code, Title 10, Part 50, Section 109, 1972, p. 289.

18. Ebbin and Kasper, Citizen Groups. . ., p. 55.

19. U.S. Code, Title 18, Chapter 39, "Explosives and Other Dangerous Articles." (Washington, D.C.: U.S. Government Printing Office), 1977, pp. 831-836.

20. U.S. Code, Title 46, Chapter 7, "Carriage of Explosives or Dangerous Substances," Section 170 (Washington, D.C.: GPO, 1971), pp. 11304-11310.

21. U.S. Congress, Senate. Clean Air Amendments of 1970, Public Law 91-604, 84 Stat. 1676. U.S. Code, Congressional & Administrative News, 91st Congress - Second Session, 1970, Vol. 1 (Laws), pp. 1965-66.

22. U.S. Environmental Protection Agency, Office of Radiation Programs, 40 CFR 190, Environmental Radiation Protection Requirements for Normal Operations of Activities in the Uranium Fuel Cycle, Final Environmental Statement, Vols. I and II (EPA 520/4-76-016), November 1, 1976.

23. Reorganization Plan No. 3 of 1970. U.S. Code, Congressional & Administrative News, 91st Congress - Second Session, 1970, Vol. 3, pp. 6322-6336.

24. Reorganization Plan No. 3 of 1970. . .

25. U.S. Environmental Protection Agency, 40 CFR 190, Environmental Radiation Protection Requirements. . ., Vol. I, p. 7.

26. Ibid., Vol. I, p. 9.

27. National Academy of Sciences-National Research Council, The Effects on Populations of Exposure to Low Levels of Ionizing Radiation, Report of the Advisory Committee on the Biological Effects of Ionizing Radiation (Washington, D.C.: NAS-NRC, January 1972).

28. U.S. Environmental Protection Agency, 40 CFR 190, Environmental Radiation Protection Requirement. . ., Vol. I, p. 11.

29. Ibid., Vol. I, p. 9.

30. Ibid., Vol. I. p. 25.

31. Ibid., Vol. I, p. 26.

32. Ibid., Vol. I, p. 12.

33. Ibid., Vol. I, p. 26.

34. Ibid., Vol. I, p. 15.

35. Ibid., Vol. I, p. 21.

36. Ibid.

37. Ibid., Vol. I, p. 47.

38. Ibid.

39. Ibid., Vol. I, p. 48.

40. Ibid., Vol. I, pp. 80-86.

41. Ibid., Vol. I, pp. 50-51.

42. Ibid., Vol. II, p. 39.

43. Ibid., Vol. II, p. 21.

44. The discount rate implicit in the summation of lives is the solution to the equation:

$$\sum_{t=1}^{t=100} V_t L_t = \sum_{t=1}^{t=\infty} V_t L_t \;/\; (1+r)^{t-1}$$

Here, V is the valuation of life in the t-th year, L_t the number of lives in that year, and r is the discount rate, assumed to be constant. If the number of lives per year were constant, out to infinity, and the valuation of life a constant, the implicit interest rate would be 0.010101... For the case at hand, there are more lives at risk in the earlier years, and so the implicit interest rate is even lower. On the other hand, if we assume an increasing absolute valuation of life, the discount rate would be higher. Given the probable distribution of lives saved, it is highly improbable that the implicit discount rate is higher than the discount rate used for reducing control costs to present worths.

45. U.S. Environmental Protection Agency, *40 CFR 190, Environmental Radiation Protection Requirements. . .*, Vol. I, p. 39.

46. Ibid., Vol. I, p. 49.

47. Ibid., Vol. I, p. 48.

48. Ibid.

15. Publicly Voiced Criteria for Nuclear Waste Material

Issues of how and where the United States should dispose of its nuclear wastes have not focused in the mind of the average American. When asked about possible dangers of nuclear power, only a small minority mention the waste disposal problem. Yet when asked directly whether disposal of wastes represents a major problem that must be surmounted, a sizeable majority agree. Environmental pressure groups rank the disposal problem high among risks of nuclear power, but even the more sophisticated do not offer positive criteria for an acceptable disposal alternative.

When the issue of disposal appears in nuclear power plant siting hearings or other public forums, the principal response from environmental groups and other citizens' bodies has been criticism of publicly available studies, and an insistent reliance on process. Demands are typically made for further studies to discover a "safe" disposal alternative. A milder response is to request that evidence be presented to the public at large, in the apparent hope that full and open discussion will in itself bring forth a generally acceptable disposal alternative.

Some critics of nuclear power development regard the issue of waste disposal as subordinate, feeling it to be less dangerous and relatively unimportant compared with hazards of power plant operation. An example of this attitude can be found in an article generally skeptical of the promises of safety of nuclear power by Richard Rhodes. He says ". . . but the problem of nuclear wastes disposal will almost certainly be solved." 1/ By January, 1977, however, the perceived dangers of waste disposal were sufficiently newsworthy for the National Broadcasting Company to show an hour-long program on the issue, emphasizing the insidious dangers of unseen horrors. 2/

Even proponents of nuclear power can become opponents of waste storage if it appears that the materials might be emplaced in close geographical proximity to themselves. In a letter commenting on the draft EPA Radiation Protection Requirements, two Iowa scientists thought the proposed standards were "unscientifically based," "extremely short-sighted," "academic," and "indefensible." They further commented that since "Iowa is a vital food production State instrumental in feeding the nation and the world, it is hoped long-time storage or processing of radioactive wastes in our State would be discouraged." 3/

Position of Public Interest Groups

Critical Mass, a monthly publication by the Ralph Nader-sponsored organization, lists reports in almost every issue from critics of ERDA's plans for

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waste management. These articles contain much information about the present and future dangers of radioactive wastes. They contain many examples of what critics call mismanagement of the ERDA search for disposal alternatives, but there is so little in the way of what is considered a safe acceptable alternative that it is futile to use these critical reports in a search for positive criteria. Four principal themes are contained in the substance of these criticisms:

1. Nuclear wastes are extraordinarily dangerous, representing risks of a qualitatively higher order than any other ever faced by society.

2. The Federal Government, and ERDA in particular, are guilty of mismanagement, for too few resources have been directed toward resolution of this problem. Continuation of nuclear power plant development should be delayed until solutions have been found to all possible dangers, including disposal of wastes.

3. The government and private industry concerned with nuclear power have hidden the truth about many dangers and problems that remain to be solved.

4. Much uncertainty remains about certain basic scientific facts that must be understood before any proposed disposal alternatives can be judged as safe.

These attacks are not frivolous. Nor is it irresponsible to criticize the presently offered disposal alternatives and point out management errors without offering positive suggestions in such a highly technical policy field. As noted, however, review of these criticisms sheds no light on what the critics would accept as a safe disposal alternative. They do not voice positive criteria.

The most informed position among the public interest groups is that of the Natural Resources Defense Council (NRDC). Their Citizens' Guide is far superior to other public interest group reports in both quality and apparent objectivity of handling of the issues. 4/

Their principal position is one of forcing the government to study further the consequences of alternatives for disposal (in the generic sense of disposal). They place reliance on further study by the government rather than offering their own specific criteria for acceptability. They also urge citizens to take an active part in NRC licensing procedures, and to intervene in hearings for power plants and spent fuel reprocessing plants.

The NRDC sees disposal through transmutation as a promising option.

> The elimination of 99.5 to 99.9% of the actinides in high-level wastes through partitioning at reprocessing plants and transmutation in existing light water reactors has been shown to be a technically and economically feasible process.

> Higher efficiencies of removal seem likely in the near future. However, making this a commercially practicable procedure will require several years of government-financed research and development. 5/

This position of seeing hope for transmutation remained alive in 1977. In the opinion of Terry Lash, an author in Citizens' Guide, further installation of nuclear power should be stopped until increased funding for transmutation research developed an acceptable disposal solution. 6/ In Lash's prepared statement before the Energy Facility Siting Council of Oregon, he also suggested a specific rule to be applied to possible certification by the state of proposed nuclear power plants.

> A site certificate shall not be issued unless (a) there is reasonable assurance of a thirty-year fuel supply for the proposed nuclear power plant; (b) there is a fully approved and licensed permanent disposal facility for commercial high-level radioactive wastes with sufficient capacity to contain thirty years' generation of high-level radioactive wastes from the proposed nuclear power plant; and (c) the site certificate applicant has obtained a firm, fixed-price contract either for reprocessing of thirty years' generation of irradiated fuel, including the disposal of high-level radioactive wastes, or for the disposal of thirty years' generation of irradiated fuel. 7/

The first clause suggests that Oregon should not permit power plant siting until there is a reasonable prospect that power plant operations, once begun, will not be interrupted or discontinued because of unforseen difficulties related to the delivery of fuel. The second clause would delay issuance of a siting certificate until a permanent disposal facility is actually in operation. In effect, it regards the present-day practice of temporary storage as unacceptable. Holding in abeyance the controversies about dealing on a permanent basis with nuclear wastes, the rule would halt power plant development and further production of wastes until a permanent, acceptable disposal method is found. In his testimony, Lash also states:

> . . .there is great uncertainty about whether or not the federal government will correct existing inadequacies of its program to meet its legal obligations and resolve the political difficulties associated with waste disposal. 8/

In other words, no acceptable disposal alternative may ever exist, and Lash suggests that Oregon delay power plant siting until the uncertainty is resolved. His third clause suggests a practical test of whether a disposal alternative really exists. Given the present ERDA policy of private operation of waste reprocessing operations, adoption of this proposed rule would provide an operational criterion of whether a disposal alternative existed, at least within the contemplated 30 year life span of the suggested commitment.

Lash's suggested rule comes as close as any offering in the public literature toward establishing a positive criterion for an acceptable waste management alternative. His criterion is economic, not technological. Uncertainty, to the Oregon siting board, which is the regulator of the power plants in question, and the energy-consuming Oregon public, would be reduced along one dimension. Economic uncertainty would be shifted to whatever body would offer the "firm, fixed-price contract" for waste disposal.

Results of Public Surveys

Results of a survey by Louis Harris and Associates of public attitudes toward development of nuclear power showed that perceived risks of nuclear waste ranked higher than any other problem associated with nuclear power development. 9/ The survey was conducted in March and April, 1975, with a nationally representative sample of 1,537 persons aged 18 and over. In addition, 301 interviews were conducted with neighbors of nuclear power plants, and 201 interviews with "leaders" -- elected and appointed government officials, vice presidents of public affairs in large and medium companies, regulatory officials of agencies such as ERDA, NRC, EPA, and state commissions, and members of environmental groups such as the Sierra Club.

In open-ended questioning on "the two or three main disadvantages of nuclear power plants to produce electric power," 10 percent of the general public mentioned problems with nuclear waste disposal, slightly more than the 9 percent of the presumably more sensitized nuclear power plant neighbors. When asked the same question, nuclear waste was identified by 50 percent of the environmentalists, 37 percent of the political leaders, 34 percent of the regulatory officials, and 22 percent of the business leaders. While in this open-ended format of questioning, waste disposal ranked fifth in the frequency of response among the general public; it ranked first among environmentalists, and regulators, and second among political leaders. Other problems which were presented more often by the general public were generalized fears of power plants being "unsafe, (and) dangerous," mentioned by 23 percent; and more specific risks such as the "danger of radiation contamination, leaks, cracks in reactor," noted by 20 percent of the general public. The "danger of accidents, explosions, and earthquakes was mentioned by 14 percent as shown in Tables 10 and 11.

Under direct questioning, the dangers of wastes became the most critical problem associated with nuclear power. When asked whether "the disposal of radioactive waste materials which remain radioactive for many centuries to come" was a major problem, 63 percent of the general public agreed, a greater percentage than was associated with any other problems in the survey. "The escape of radioactivity into the atmosphere," presumably the major danger associated with power plant operations, was thought to be a major problem by 49 percent. Among the leadership groups, direct questioning again brought widespread agreement that waste disposal was a major problem.

In the open-ended question format, risks of radioactive waste disposal are mentioned by a relatively small percentage of the general public. However, when a direct probe brings forth the issue, a much higher percentage not

TABLE 10

Extract of Results of Open-Ended Questioning on "The Two or Three Main Disadvantages of Nuclear Power Plants To Produce Electric Power" (Percent Responding)

Disadvantage Cited	Total Public	Political Leaders	Business Leaders	Regu- lators	Environmen- talists
Unsafe, Dangerous	23	16	24	15	15
Danger of Radiation Contamination, Leaks, Cracks in Reactor	20	41	25	30	37
Danger of Accidents Explosions, Earthquakes	14	4	14	15	27
Thermal Pollution Kills Marine Life	12	14	10	21	12
Problems with Radioactive Waste Disposal	10	37	22	34	50

Source: Louis Harris and Associates, Inc., A Survey of Public and Leadership Attitudes Toward Nuclear Power Development in the United States, conducted for Ebasco Services, Inc., New York, August 1975, page 55.

TABLE 11

Agreement with Stated Problems Connected With Nuclear Power Plants
(Percent Agreement)

Statement	Total Public	Political Leaders	Business Leaders	Regulators	Environmentalists
The Disposal of Radioactive Waste Materials Which Remain Radioactive for Many Centuries to Come					
Major Problem	63	82	57	76	98
Minor Problem	14	10	29	20	2
The Escape of Radioactivity Into the Atmosphere					
Major Problem	49	33	22	39	62
Minor Problem	19	29	14	28	25
The Chance of an Explosion in the Case of an Accident					
Major Problem	47	14	18	17	45
Minor Problem	28	37	29	43	29
The Discharge of Warm Water into Lakes and Rivers that Could Endanger Fish and Other Water Life					
Major Problem	47	43	22	44	58
Minor Problem	28	45	51	40	38

Source: Louis Harris and Associates, Inc., A Survey of Public and Leadership Attitudes Toward Nuclear Power Development in the United States, conducted for Ebasco Services, Inc., New York, August 1975, page 56.

only thinks disposal a major problem, but the issue also tops the list of all perceived problems. Two comments explain this apparent inconsistency. First, the public may not perceive waste disposal as a systems problem of the entire fuel cycle. Second, the problem may still be too sophisticated to be generally perceived by the public. The high number of interviewees who perceive the risk as major may be a matter of the emotive language used -- e.g., "remain radioactive for many centuries to come." On the other hand, "the possibility that plutonium, which is made in a nuclear power plant, could be stolen by radical revolutionaries" (emphasis added) also contains emotive language, yet was well down the scale of agreement as a major problem.

Another survey, conducted by the Battelle Memorial Institute, attempted to probe more deeply into public attitudes and values toward waste disposal by use of a highly structured questionnaire in conjunction with a variety of sophisticated psychometric techniques. 10/ The survey was conducted in early 1976, and obtained 465 usable responses from persons associated with a variety of groups -- nuclear technologists, environmentalists, high school and university students, public utility employees, and members of civic organizations. The basic purpose of the study was to probe and attempt to quantify four basic dimensions of public attitudes toward nuclear waste disposal.

1. Short-term safety: those risks involved in the storage, transportation, and emplacement of nuclear waste materials.
2. Long-term safety: that portion of total risk which would begin after wastes were finally emplaced or disposed and which would continue for the next 250,000 years.
3. Cost: the dollar cost required for a given waste disposal method.
4. Accident detection and recovery: steps that could be taken to reduce the consequences of an accident if it should occur after final disposal. 11/

Despite the many elaborate psychometric techniques employed to analyze the survey responses, the principal conclusions of the study are simple, occasioning no surprises. By a significant margin, cost is felt to be the least important factor associated with waste disposal methods. Among the other three, Long-term safety received the highest priority by a small margin over the other two factors.

Various scaling techniques were employed to attempt to quantify the priorities. All methods seem suspect because no real trade-offs were ever necessary -- the answers may well have been heavily dependent on the particular scales of the choices offered. Not surprisingly, the Nuclear Technologists rated various levels of Short-term and Long-term risk as more satisfactory than did other groups, while the Environmentalists gave the lowest ratings to various levels of risk. In general, these two groups bounded the responses to all attitudinal questions, with the other groups falling somewhere in between.

Despite the very caveats that may be raised against the scaling techniques employed, results of the study in this area should be reported. On Short-term safety, Nuclear Technologists and Environmentalists were the least and most risk-adverse, respectively, while views of the other groups more closely resembled those of the Environmentalists. Reasonable levels of satisfaction were associated with one death per year.

On Long-term safety, the mid-point on the scale again was associated with one death per year with more extreme views held by Environmentalists and Nuclear Technologists.

On the issue of Cost, feelings about Satisfaction were associated with a scale running from $15.00 and higher per month in increased monthly costs of electrical power. Given the low priority attached to Cost, even an increase of $15.00 per month was near the mid-point of the scale, far from Very Unsatisfactory. General agreement was reached that increases of $3.00 to $5.00 per month would be quite satisfactory.

The best source of views of the general public when actually confronted with the possibility of having nuclear wastes stored in close proximity to their places of work and homes comes from hearings on nuclear waste disposal in Michigan, held by Representative Bob Carr, Democrat of East Lansing, presiding. 12/ The hearings concerned ERDA's plan to conduct test drillings to investigate suitability of the Salina salt beds in Michigan as possible sites for nuclear waste storage. Statements were obtained from 26 persons, principally from local citizens' groups, environmental interest groups, and various levels of Michigan government. The statements featured recitations about dangers of transportation and possibilities of danger from nuclear wastes. The unfortunate history of the Lyons, Kansas exploration was noted, along with other tales of various mistakes made by the AEC and other bodies in charge of nuclear wastes.

Much of the testimony was devoted not so much to staking out a position either in favor of or against local disposal of nuclear wastes, but rather a call for citizen input, full dissemination of information, and clear exposition of the processes and risks so that an informed citizenry could make a decision. Perhaps the clearest exposition of this view was given in the prepared statement of Congressman Philip E. Ruppe, Republican, of Houghton:

> These decisions will have to be reached by all of us. They cannot successfully be concluded by Congress alone, by executive agencies, such as ERDA, alone, or by state and local governments alone. We will all have to develop that policy together, for we all have a vested interest in the outcome of the decision.
>
> As important as that final decision is, however, of equal importance is the method we use to reach the decision. It is my belief that there is only one path that will make the ultimate choice a fruitful one. That method involves open discussion and open debate

> about all alternatives involving every issue of the nuclear power question. 13/

The Governor of Michigan felt "strongly that information regarding preliminary testing and future development of a proposed area must be made available to everyone." 14/ This emphasis on process as necessary and correct in order to reach the best decision was echoed by the Michigan United Conservation Clubs. After expressing that they were "skeptical whether ERDA can prove to the satisfaction of the state that disposal of nuclear wastes will be safe," they stated:

> "We believe the citizens of Michigan will agree with a decision to site a nuclear dump in our State if the proposal is fully aired and shown to be safe as supported by the evidence." 15/

Summary

From the discussion above, there appears to be relatively limited concern about risks related to nuclear wastes as compared to other risks within the nuclear power cycle. Conversely, those who do perceive risks from nuclear waste management are quite vocal and hold strong opinions often based on misinformation, lack of knowledge, or both. Perhaps most important, there exists a somewhat definitive, unanimous, and strong desire on the part of the public for complete and absolute public disclosure of all facts related to nuclear waste management decisions prior to the making of any decision. Operational implication of these attitudes are quite clear: any risk analysis of nuclear waste undertaken as part of the management process must be as detailed as possible and must be made available to the greatest extent possible to the general public.

Notes to Chapter 15

1. Richard Rhodes, "Delusions of Power," The Benefits, Costs, & Risks of Nuclear Energy. The Atlantic (June 1976), p. 41. In this report, the views of two prominent environmental groups are summarized. The principal results of two surveys of attitudes towards nuclear waste disposal are also presented. Useful evidence on public attitudes is contained in Congressional hearings in Michigan relating to choice of a nuclear waste disposal site in that state.

2. National Broadcasting Company, "Danger: Radioactive Waste," (January 26, 1977). Unfortunately, NBC did not collect audience participation statistics on this program. We have no way of knowing whether this program attracted more than the usual small audience for special news topics.

3. Rolf M. A. Hahne, and Robert L. Morris, to the EPA, reprinted in U.S. Environmental Protection Agency, Office of Radiation Programs, 40 CFR 190: Environmental Radiation Protection Requirements for Normal Opera-

tions of Activities in the Uranium Fuel Cycle, Final Environmental Statement (EPA 520/4-76-016), Vol. II, p. A. 14-15.

4. Natural Resources Defense Council, Inc., *Citizens' Guide: The National Debate on the Handling of Radioactive Wastes from Nuclear Power Plants*, by Terry R. Lash, John E. Bryson, and Richard Cotton (Palo Alto, Natural Resources Defense Council, Inc., November 1975).

5. Natural Resources Defense Council, Inc., *Citizens' Guide. . .*, pp. 25-26.

6. Telephone conversation with Terry Lash, Natural Resources Defense Council, February 2, 1977.

7. Terry R. Lash, "Prepared Testimony Before the Energy Facility Siting Council of Oregon," January 11, 1977 (mimeo), p. 5.

8. Terry R. Lash, "Prepared Testimony Before the Energy. . .," p. 16.

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16. Evaluation of the Decision Process as Applied to Nuclear Waste Management

Options for managing nuclear wastes are numerous, as discussed previously. Management of nuclear waste can be meaningful only if the public is assured that risks are minimal and if cost-benefit analysis indicates a socially acceptable outcome. The option selected must be virtually flawless in order to gain credibility from the general public as well as the scientific community. At the present time, few members of the scientific community and perhaps even the general public favor disposal concepts such as extraterrestrial transport. Consequently, geological isolation appears to be the only currently viable alternative. Thus, appropriate risk analysis of this disposal concept is an integral part of the decision process. Risk analysis can essentially be based on either of two approaches: (1) evaluation on the basis of empirical data (an actuarial approach); or (2) evaluation of risks based on predictive techniques which combine known subset failure data with an understanding of system failure modes.

The actuarial approach is appropriate where data from similar past occurrences are available and the future is expected to be similar to the past. For example, reasonably good data exists on transportation accidents. These data can be used to predict accident frequencies involved in high-level waste transport, provided that the transport is effected by conventional means. However, no complete set of data exists on the reliability of high-level waste storage facilities. Only partial data are available for assessing the risk associated with storing high-level wastes. Therefore, for these facilities, risk analysis such as the fault tree methodology used in the Rasmussen study to predict reactor safety must be used in spite of data problems associated with such an analysis.

Risk Analysis of Geologic Disposal Methods

The principal difficulty with data related to geological disposal of nuclear wastes arises from the instability of geological formations over long periods of time. A first approach would be to estimate future risks on the basis of past performance. Thus, in assessing future stability against earthquakes, volcanoes, or the presence of water, the geologic age since the last occurrence of any of these events might be used as an estimate of the future time scale over which such an event would not occur again. The assumption of this homogeneity in nature, however, could be misleading. Over periods considered short in comparison to the geologic times involved, this approach is probably acceptable. For example, in the near future, areas of low earthquake probability in the past will be subject to fewer earthquakes than areas of past high earthquake frequency. For predictions over long periods of time, however, past performance may be a poor indicator of future performance as the earth is in a state of noticeable dynamic change. For example, present plate tectonic theory shows that the ocean floor is in a constant state of change, with new material being added continuously, drifting across the ocean, and then being subducted below the earth's crust again. In light of this phenomenon, the oldest rocks will have the shortest future life while newly created rocks will have the longest future life.

These problems are fundamental in analysis of risks associated with geological disposal of nuclear waste. Some of these problems, however, can be minimized by appropriate risk analysis involving six basic tasks:

1. Estimation of engineering and component failures
2. Estimation of human failures
3. Estimation of unanticipated natural events
4. Pathway analysis
5. Receptor distributions analysis
6. Health effects analysis

A brief description of these tasks is provided below.

Engineering and component failures. For the geological disposal concept, reliance on engineering is relatively large. However, this task is not an overriding component of a hazard analysis of waste management, because most of the required data are available and research methodology well established.

Human failures. Human failures can be estimated fairly accurately in the limited sense of routine mistakes during known operating steps. However, estimation of human failures in the larger sense of social or political instability is clearly uncertain. This uncertainty has a high impact on waste disposal concepts which require continued maintenance or surveillance by man, such as storage in engineered surface units. For systems with relatively short lifetimes, the inability to estimate future social and political stability may not be critical, but for systems with anticipated lifetimes on the order of a hundred or more years, the inability to analyze the risk from large-scale human failure makes it difficult to assure future generations that small risk is involved. This fact is a definite disadvantage of engineered storage systems which might require human intervention to maintain integrity.

Another area with a high degree of uncertainty is the estimation of failure from deliberate human action such as sabotage. Additional research is needed before a low risk from storage in areas easily accessible to man, such as surface storage, could be assured.

Unanticipated natural events. The estimate of natural disasters through relatively frequent occurrences such as tornadoes or lightning strikes is well understood. The risk from events such as earthquakes over the short term is also reasonably well known, but is less understood over the longer-term. The risk from longer-term geologic events such as ice ages, melting of the ice caps, and change of continental shapes is relatively unknown. The risk from dependence upon geologic stability over short periods of time is fairly well known, but the risk associated with dependence upon geologic stability over geologic times (on the order of a million years) is essentially unknown. These facts tend to rule against disposal schemes in which isolation is needed for long periods and the disposal medium is either relatively vulnerable or does not provide good isolation from biota. This would include disposal in vulnerable salt deposits or disposal in sea or ice environments which could lead to rapid dispersal of the waste material to living organisms. If long-term isolation of wastes is needed, deep rock formations which provide good isolation and invulnerability characteristics as well as apparent stability would be a preferable medium.

Pathway analysis. Uncertainties in pathways analysis do not appear as significant as uncertainties in estimating the initial basic failure. Limiting consequences can always be calculated by making conservative pathways assumptions. However, basic data on the travel of radionuclides over long time scales are only partially understood. The migration of many different isotopes through soil and concentrations in various media have been the subject of numerous studies. These data typically encompass a few years or perhaps tens of years' data, and over-reliance on holdup in soil should not be relied upon for extended periods of time. This is significant in cases such as Hanford, where retention in the soil is presumed to isolate large quantities of long lived isotopes from more critical systems. Continued reliance upon such mechanisms, or future reliance on such mechanisms in other disposal schemes, does not appear wise given the long-term pathway uncertainties.

Receptor distributions. Receptor distributions and ultimate health effects are fairly well known, and only large relative uncertainties are likely to have profound effects on the choice of disposal methods. However, some uncertainties of this nature do exist. The most obvious uncertainty pertains to the health effect of long lived alpha emitters, such as plutonium.

Health effects. Consideration of health effects in risk analysis management is always paramount, and yet ultimately these effects are relatively unknown. Large-scale leakage would almost always be catastrophic. Slow undetected leakage could have global effects half a century from today. In the same manner that very fine particulates take from 20 to 40 years to produce cancer, suspicions that radioactivity and its effects on humankind might behave in a similar way seem realistic. The effects of such radiation over the long term are much more subtle, but could well be far reaching and more destructive for much longer periods of time.

If quantitative risks can be determined for different waste management concepts, one possible way to choose among the concepts would be to minimize a summation over all types of release events integrated over all time; that is, minimize the quantity

$$\Sigma_i \int_t P_i(t)\ C_i(t)\ T_i(t)dt$$

where $P_i(t)$ is the time dependent probability of release for release type i, $C_i(t)$ is the consequence of this release, and $T_i(t)$ is a future weighting factor.

Regarding the choice of a future weighting factor, it might be possible to assign equal weight to future risks as present risks; i.e., let T_i equal unity for each future time period. Another approach would be to discount future risks in the same manner that future costs are discounted in making economic comparisons. The choice of a future weighting factor depends upon our perceptions of the future world and our responsibility for the future. The choice is clearly societal, not technological.

With regard to future weighting factors, the type of risk posed must be considered. If it is known that future risks can be modified with a reasonable amount of capital or effort, these future costs should probably be discounted in making present decisions. However, in the case of nuclear waste release, the likely risk will often be an irretrievable loss of land areas, water systems and human activity for very long periods of time. The principal difficulty with these "future weighting factor(s)" is, of course, the need to relate them to the value of the consequences that may result. Establishing values acceptable to all major groups in society can be a difficult if not impossible undertaking.

Health risks are obviously a critical area for consideration. Over the short run, a future cancer risk to the population is probably of equal negative value as a present cancer risk. However, over very long periods of time, future and present cancer risks are not comparable if cures for cancer can be assumed over the long run. In that case, greatly distant cancer risks should be largely discounted in comparison to present cancer risks.

Another problem in the use of overall risk summations as a measure by which alternatives can be evaluated is that the same average number of fatalities may be incommensurate. This is especially true when considering time-integrated total risks.

Waste Management Decisions

Clearly, the overriding issue is whether nuclear waste management poses an acceptable risk, or whether nuclear power should be curtailed to avoid creating further nuclear waste. This decision is not simply technological. Specifically, societal perceptions of future risks are an important part of any waste management decision. However, technological analysis suggests that if nuclear wastes are carefully handled (for instance, fractionation recycle and transmutation of long-lived activity), the potential risks may be no greater than those posed by many of man's presently accepted activities, even accounting for the full future risk potential of nuclear waste. Mishandled nuclear waste, on the other hand, could pose a truly significant hazard to this generation and many future generations.

At the level of selecting among waste management alternatives, certain features stand out. First, the cost of most waste disposal systems represents only a small fraction of the total cost of electricity. At the same time, mistakes in waste handling can lead to large future cost commitments, or even large potential health risks. This possibility suggests that any decisions in this regard should undergo much more complete risk analysis than has been made in the past.

Although costs of waste management are likely to be a small fraction (typically less than 1%) of the total cost of electricity, they will represent large absolute costs. 1/ Awareness of this likelihood is particularly important when these costs may be borne entirely by an isolated segment of the total nuclear electricity cycle. The degree of actinide separation in reprocessing spent fuel provides a good example for potential mismanagement. Within the present nuclear fuel cycle, the spent fuel reprocessor must operate on the small savings represented by the recycle of spent fuel. 2/ Regulations governing this part of the fuel cycle could conceivably result in no fuel processing at all. From the waste management standpoint, this would result in maximizing the amount of long-lived activity in high level waste. Waste management decisions and regulations must be taken in the context of the entire nuclear picture. Also, where society would benefit by requiring certain waste management practices, methods should be considered to assure that the costs of such decisions and regulations are borne by the ultimate users of electricity, and not by an isolated portion of the nuclear fuel cycle.

Another good example of how risks from waste management affect risk in other activities is the trade-off which must be made between immediate risks posed by plutonium recycle and the long-term reduction in risk which can be achieved by eliminating plutonium through recycle. These risks are interdependent. To analyze, regulate or manage these risks in isolation could lead to wrong social decisions, with serious consequences.

At present over 20 different agencies are involved in attempting to coordinate nuclear power management decisions. These agencies are carrying out supposedly well established goals, unique to each agency. However, the operation of nuclear plants, guidelines for management, and regulations for licensing power plants all require a unique kind of coordination and exchange of information if correct trade-offs and decisions are to be made. The difficulties faced by these 20-odd agencies in trying to achieve coordinated efforts appear at times overwhelming. It should not be surprising that the situation often results in fragmentation and lack of communication.

Criteria for Evaluating the Decision Process

The problem of deciding upon the appropriate waste disposal alternative depends on the low probability of a bad occurrence with any seriously proposed waste disposal mechanism, coupled with the high consequence of an accident. Limited knowledge concerning many aspects of nuclear waste disposal implies that complete agreement on the expected outcome is impossible. Thus, no matter which alternative is selected, any decision now on the appropriate form of nuclear waste disposal would generally elicit a significant divergence of opinion.

In addition to the general limitations on knowledge, nuclear wastes hold profound implications for future generations. Some recognition of preferences regarding future generations must be made during the decision process. The decision among waste disposal alternatives is important, yet the uncertainty inherent in any waste disposal mechanism implies that the ex post correct decision will not be known for many years. Public acceptance of the selected disposal mechanism therefore requires that the process be one which the public believes will give an incorrect decision a very low probability.

Part I of this study developed a set of criteria for evaluating the social decision process in situations such as nuclear waste disposal. In this concluding Chapter of Part III, we shall evaluate the decision process used in nuclear waste disposal by reference to the eight criteria specified in Part I, Chapter 4. For ease of reference, these criteria are listed in the accompanying Table 12.

1. Are parties who incur the present costs adequately represented?

Parties presently at risk are all members of the general public who may be exposed to radiation from nuclear waste. Costs are borne by members of the public who will suffer health damage as the result of this exposure. As in the case of pesticides, some of the monetary part of this burden, namely the cost of treatment covered by health insurance, is spread directly among the general public. However, since everybody is potentially at risk, to quite a large degree it is the general public that may be affected.

During the earlier stages in development of nuclear power, the AEC attempted to limit the scope of public hearings on new facilities. Groups living near the proposed sites were heard. However, the AEC tended to exclude from consideration broad issues of public interest, such as the creation and management of nuclear wastes. This attitude was one factor underlying the reorganization of the government's nuclear programs. The interest of the general public is now represented by NRC, EPA and Department of Energy from within the public sector. Private sector still has had only marginal representation in the issue of nuclear waste disposal *per se*, because of its emphasis on other issues related to the nuclear power cycle and because the final criteria and related issues are still being developed by the Federal Government.

As noted in the case study on pesticides, the adequacy of representation on behalf of parties who bear the present costs depends on the financing of those representing the general public. Because nuclear waste management is a complex and highly technical subject, the need for expertise is cardinal. At the same time, most environmental action groups are poorly financed. If the private sector is to be adequately represented, some means may have to be found to enable the private sector to pay for this expertise. This raises the issue of whether some means should be instituted for compensating parties who intervene in nuclear waste management proposals on the side of those who bear

TABLE 12

Criteria for Evaluating Decision Processes Embodying Low Probability, High Consequence Risks[*]

1. Are parties who incur the present costs adequately represented?

2. Are parties who receive the present benefits represented?

3. Are interests of future generations suitably considered?

4. Are the distributional aspects considered systematically?

5. Are the social decision-makers unbiased and open?

6. Is the development of knowledge concerning the effect of possible alternative decisions adequate?

    a. Do views that appear to come from reasonable sources receive -- or appear to receive -- "equal time and treatment"?

    b. Are all significant differences considering the quality of knowledge included?

    c. Are the gaps in knowledge identified?

    d. Are procedures for collecting knowledge of the area efficient?

    e. Are the plausible consequences spelled out for the worst contingency?

    f. Are alternatives suitably considered?

7. Is information given to the individuals who are at risk?

8. Can a decision change if significant new information is obtained?

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[*] Source: Part I, Theoretical Considerations, Chapter 4, pp. 31-35.

the present (or future) costs. Precedent for such compensation exists within the legal process. In a class action suit, the attorneys representing the plaintiffs can expect to receive fees if they are successful. Further, expert witnesses and related costs can also be expected to be paid in such suits.

One additional overriding factor favors such compensation in the case of nuclear waste. We are referring, of course, to the fact that management of nuclear waste is undertaken by the Federal Government and therefore there exists the danger of a conflict of interests on the part of Government institutions/agencies that regulate waste disposal. This factor does not exist in the case of pesticides.

2. Are parties who receive the present benefits represented?

No single population group benefits directly from nuclear waste management. Of course, those who benefit from nuclear power will gain measurably if any scheme for management or disposal of nuclear wastes were to receive broad social acceptance. Proponents of nuclear power can be expected to have adequate representation at any hearing relating to nuclear waste.

3. Are the interests of future generations suitably considered?

Unlike the case of pesticides, potential impacts of nuclear waste transcend generations. As a matter of fact, no other man-made event creates longer lasting effects than waste resulting from nuclear power production. As indicated in previous chapters, considering the interests of future generations is one of the most difficult issues. As also indicated previously, this issue may lie beyond the competence of economists or administrators and in the realm of theologians and philosophers.

Little can be said here about this issue except to note that if waste management uses all six task analyses described in the first part of this chapter, the interests of future generations are considered as much as is possible, given the unique characteristics of nuclear waste.

4. Are distributional aspects considered systematically?

To date, no party in the debate on nuclear waste disposal has raised distributional aspects as an important issue. That is, all parties have implicitly assumed that benefits and costs of disposal activities will be spread widely among the population. This may well be the case. There is no established mechanism, however, for systematically inquiring into distributional aspects.

5. Are decision-makers "unbiased" and open?

A number of issues relate to this criterion. First, as described elsewhere in this study, nuclear waste management does not have well-established and prescribed procedures such as those which exist for pesticides. Second, some of the procedural issues and certainly the final criteria are still being considered. Current procedures will certainly be modified. Finally, Federal

Government officials may harbor biases toward certain waste management options with failure modes which are difficult to detect and even more difficult to correct.

The fact that the government has not adopted or embarked on any "permanent" disposal method can, on the one hand, be interpreted as displaying a high degree of unbiasedness. On the other hand, the government continues to accumulate increasing amounts of nuclear waste in "temporary" storage facilities. This indicates an implicit bias -- or faith -- that an acceptable permanent solution is technologically feasible and will be determined before the wastes held in temporary storage become unmanageable. At a minimum, the decision process has resulted in a compromise position. Such a decision process is not without bias. However, in view of the fact that development of nuclear power has noticeably slowed, the state of affairs just described may reflect bias in the former AEC decision process more than in the current decision process.

6. Is development of knowledge concerning the effect of possible alternative decisions adequate?

    a. Do views that appear to come from reasonable sources receive -- or appear to receive -- "equal time and treatment?"

Under the AEC it is not clear that reasonable views did in fact receive "equal time and treatment." The AEC no longer exists, however, and waste management discussions are a continuing dialogue. Therefore it is difficult to answer this question. With the continued growth of broad-based public interest groups, on net balance it would appear that reasonable views do now receive equal time and treatment.

    b. Are all significant differences considering the quality of knowledge included?

Analysis of past experience in the nuclear waste management discussion clearly indicates that there have been considerable differences regarding the quality of knowledge pertaining to nuclear waste management. These differences have been brought out in the open and discussed in some detail, but it is not clear whether or how these differences are taken into account in "official" considerations.

    c. Are the gaps in knowledge identified?

Analysis of the existing literature and documents on nuclear waste management identifies many gaps in knowledge and these have been discussed in considerable detail. It is likely, however, that in some cases no additional expenditures or effort will narrow these gaps within a short term period. Thus, although in the case of nuclear waste management there is adequate information on the existence of gaps in knowledge, some of these continue to exist due to the nature of the subject.

d. Are procedures for collecting knowledge of the area efficient?

Analysis of past experiences in this area, presented in Chapters 13 and 14, indicates that considerable thought has been given to the collection of knowledge pertaining to nuclear waste management. In some cases, however, even the conceptual and theoretical underpinnings are in dispute. This makes the process more difficult. A principal problem pointed up by this criterion is that there are no well-established procedures for collecting and disseminating some of the information required.

e. Are plausible consequences spelled out for the worst contingency?

A number of documents spell out in some detail the consequences of a number of contingencies. The potential disasters that could result from nuclear waste are so great that they invite the development of "doomsday" scenarios. The principal difficulty that arises from application of this criterion to nuclear waste concerns which waste management concepts would result in the worst contingency under certain conditions.

f. Are alternatives suitably considered?

As presented in Chapter 12, a number of alternatives have been considered in considerable detail, and it appears that this criterion has been satisfied by the waste management process.

7. Is information given to individuals who are at risk?

As already described there now appears to be a deliberate effort by Federal Government to provide the public with information pertaining to nuclear waste management, hence this criterion appears to be satisfied.

8. Can a decision change if significant new information is obtained?

This evaluation criterion, as much as any other, serves to protect the interests of future generations. The issue raised by this evaluation criterion is perhaps the greatest source of difficulty for all "permanent" geological disposal methods that have been proposed to date. Some methods may be more reversible than others. For example, wastes suspended in polar ice packs could be dug up and retrieved more easily than wastes that have been permanently fused into deep rock wells. Herein lies the rub. Waste disposal methods considered best by certain other criteria tend to be the most completely irreversible once completed. It is considerations of this sort which led the Natural Resources Defense Council (NRDC) to favor greater expenditures on transmutation research. To the extent that this is a valid and important evaluation criterion, it would appear that NRDC's priorities have considerable merit.

Summary and Conclusion

As discussed above, application of these eight evaluation criteria to the decision process for selecting among nuclear waste management options is often difficult because of certain unique characteristics of nuclear waste. Each criterion is subject to dispute and possible refinement. However, they do permit a broad-based evaluation of the decision process used to select among waste disposal alternatives. They also assure protection of the rights of individuals — now and in the future -- affected by the decision. This latter assurance should enhance public acceptability of the final decision.

Although public concern is often an issue in matters of policy decision, seldom has the public been more concerned than in issues dealt with here. Indifference to societal input is totally out of the question where issues of nuclear power are concerned. At one extreme, the public could conceivably put nuclear power out of business. Or they could delay action to the point where energy requirements of the nation and world became even more critical than is currently predicted.

Another implication of this case study, though briefly mentioned, is the lack of a complete systems approach toward nuclear waste management by numerous governmental entities now responsible for various aspects of nuclear energy. There can be no substitute for communication and informed action by these many governmental units. A comprehensive program plan for mutual exchange, as well as structured cooperation in their efforts, objectives and goals is needed to prevent fragmentation of our national energy policy for nuclear power.

Finally, this study indicates that nuclear waste disposal is not without grave risks, but equally, is not beyond the point of safe control—both technologically and managerially, now and in the future. The thoroughness of the approach used to resolve problems of disposal is unparalleled in magnitude, and should be so perceived. However, further studies on risk analysis methodologies and benefit-cost analysis should be carried out prior to selection of final criteria. These studies should indicate where conceptual data do not currently exist. Given the time for such studies prior to committing to a permanent method for nuclear waste disposal, the final decision can be made with a very high probability of being correct.

Notes to Chapter 16

1. The building of 1000 nuclear plants represents a present worth capital cost of about 500 billion dollars, which is equivalent to about 50 billion dollars on a levelized annualized annual basis. A one percent waste management cost would represent 500 million dollars/year.

2. If reprocessing costs per unit of uranium and/or plutonium are higher than the cost of an energy equivalent amount of newly mined uranium, utilities will clearly have no incentive to purchase reprocessed fuel material.

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